

## **3.9 RECREATION**

### **3.9.1 INTRODUCTION**

The Colorado River, Lake Mead and Lake Powell provide water-based recreation opportunities that are of local, regional and national significance, as well as international interest.

This recreation analysis addresses five specific recreation-related issues associated with potential effects that could result from implementation of the interim surplus criteria alternatives considered in this document. The issues addressed are potential effects to:

- Reservoir marinas and boat launching and shoreline access for Lake Powell and Lake Mead;
- Lake Mead and Lake Powell boating and navigation;
- River and whitewater boating;
- Reservoir fishing associated with Lake Powell and Lake Mead; and
- Recreational facilities' relocation costs.

The interim surplus alternatives would not change the current and projected operations of Lakes Mohave and Havasu and thus would not affect recreation on those reservoirs.

### **3.9.2 RESERVOIR MARINAS, BOAT LAUNCHING AND SHORELINE ACCESS**

This section considers potential effects of the interim surplus criteria alternatives on Lake Powell and Lake Mead marinas, boat launching facilities and other important shoreline access areas.

#### **3.9.2.1 METHODOLOGY**

Information in this section was compiled after review of available published and unpublished sources, and through personal communication with Reclamation, NPS and resource specialists. Thorough review of existing literature on the Colorado River provided information on reservoir recreation use for both Lake Powell and Lake Mead. Where available, quantities of facilities at each marina, boat launching ramp and shoreline access area are included.

From the information compiled, representative threshold pool elevations were selected for facilities at or below which certain facilities may be rendered inoperable or

relocation of facilities could be required to maintain their operation. These thresholds were chosen based on information provided in studies or in communications with NPS personnel. Discussions of the probabilities of these thresholds occurring is detailed in the Environmental Consequences, Section. 3.9.2.3. The probability of reservoir elevations occurring below these levels under baseline conditions and the alternatives was identified using Colorado River Simulation System (CRSS) forecast modeling as described in Section 3.3.

Data generated from the CRSS model include the probabilities (represented graphically in the environmental consequences section) of each of the alternatives avoiding (i.e., not being drawn down to below) the specified “threshold” pool elevations for each year over the 50-year period of analysis. The graphs indicate the general trend of elevation probabilities and present the incremental differences in probabilities for each of the alternatives and baseline projections.

### **3.9.2.2 AFFECTED ENVIRONMENT**

Recreational boating on Lake Mead and Lake Powell is dependent upon access to the water via shoreline facilities such as marinas, docks, buoys and launch ramps. Fluctuation in water levels is a normal function of reservoir operations, and facilities are designed and operated to accommodate it. However, decreased pool elevations or increased variations or rates in pool elevation fluctuation could result in increased operation costs, temporary closures or possibly permanent closure.

Reservoir pool elevations at Lake Powell and Lake Mead depend on annual inflow from the Colorado River upstream, and outflow from the respective dam to the Colorado River downstream for water deliveries. Operation of the Colorado River generally results in the highest pool elevations in Lake Powell in mid-summer and in Lake Mead, early winter. The lowest pool elevations tend to occur in early spring in both reservoirs. In general, however, pool level fluctuations in Lake Powell and Lake Mead tend to vary on an annual basis more than on a monthly or seasonal basis. Lake Powell historical pool fluctuations have normally ranged from 20 to 25 feet per year (Combrinks and Collins, 1992).

#### **3.9.2.2.1 Lake Powell Recreation Resources**

Lake Powell is located in the Glen Canyon National Recreation Area (GCNRA) in southern Utah and northern Arizona. Typical recreation activities that occur at Lake Powell include swimming and sunbathing, power boating, fishing, off-beach activities associated with boat trips (such as hiking and exploring ruins), house boating, personal water craft, canoeing, kayaking, sailing, and other activities (Reclamation, March 1995). A carrying capacity study (NPS, 1991) provided information on the potential limits of boater use on Lake Powell. The study also showed that the average length of stay at the GCNRA is 4.5 days.

Visitation numbers for the entire GCNRA between 1990 to 1999 are provided in Table 3.9-1. The data indicate that there is a seasonal variability in recreation use. The majority of use occurs in the summer months of June, July and August. The visitation numbers shown for 1995 to 1999 are considerably lower than visitation between 1990 and 1994 due to changes in NPS methods for calculating visitation. However, the seasonal pattern of visitation does not change, with use being highest in summer months. The majority of visitors to the GCNRA travel either less than 30 miles to visit (29.1 percent) or travel 121 to 240 miles (28.9 percent). This indicates that the area is used predominantly by local and regional visitors.

**Table 3.9-1**  
**Glen Canyon National Recreation Area Visitation**

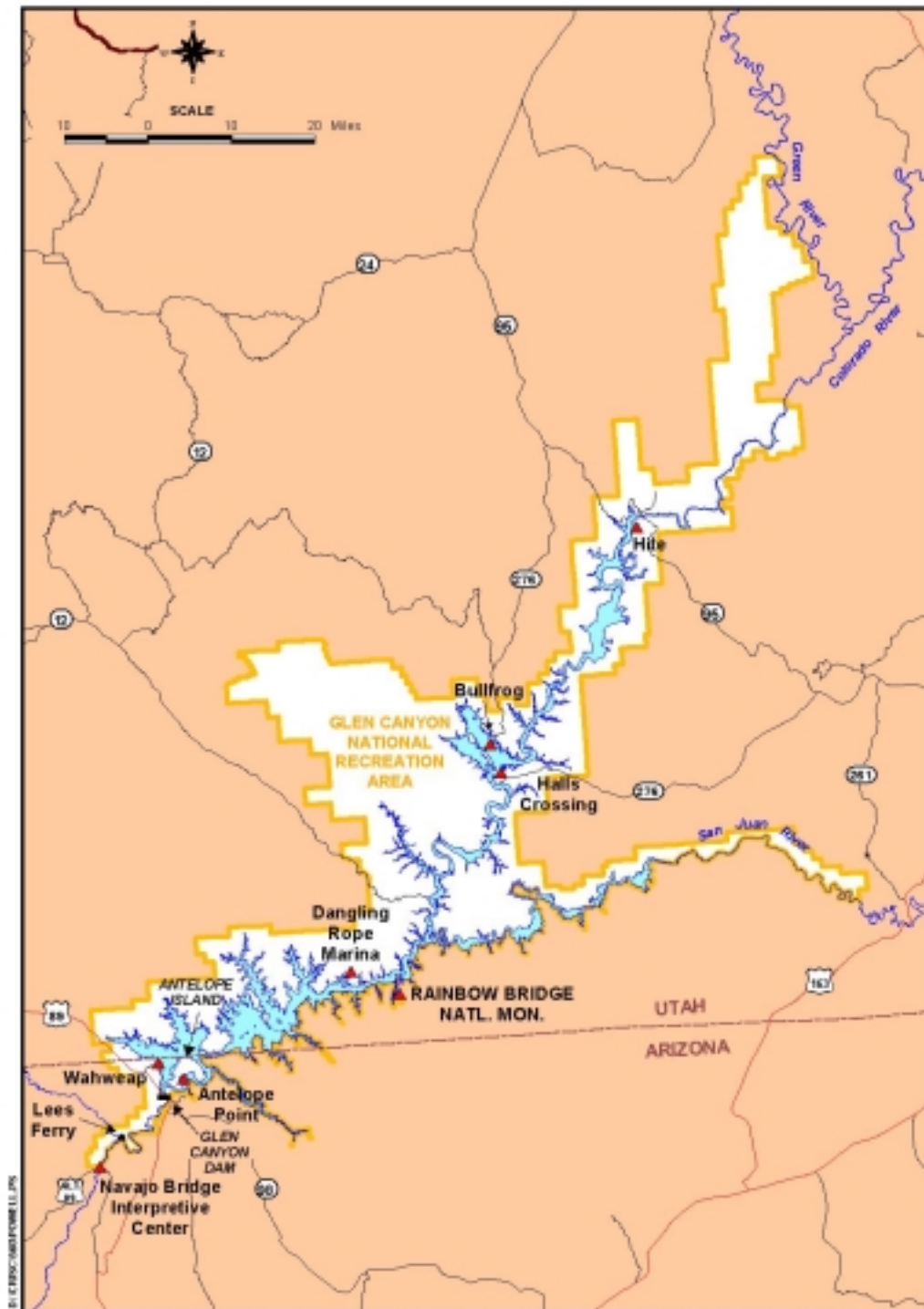
Year	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
1990	77,617	109,042	135,039	253,638	289,993	501,288	467,981	483,023	350,026	227,061	129,691	78,750	3,103,129
1991	81,875	97,120	118,182	199,462	346,764	451,674	503,752	568,030	396,785	247,982	120,822	78,442	3,210,890
1992	83,044	114,889	139,787	246,993	346,727	525,610	572,869	659,809	478,032	245,565	122,386	82,847	3,620,558
1993	60,927	83,903	123,836	201,141	372,425	526,202	624,549	644,534	530,550	259,119	111,607	76,031	3,470,194
1994	69,663	120,307	174,272	264,265	364,826	576,355	665,583	439,177	321,961	212,729	99,097	63,607	3,371,842
1995*	35,814	66,553	88,414	151,369	196,905	410,610	435,840	461,431	285,118	192,597	94,508	50,362	2,469,521
1996	41,303	50,553	96,296	209,243	231,655	419,288	447,417	442,180	268,266	187,949	89,670	48,269	2,532,087
1997	49,954	54,401	115,523	157,249	245,000	288,742	420,927	437,846	266,992	187,467	85,595	48,507	2,458,203
1998	39,241	55,538	89,971	171,234	267,509	389,167	445,423	398,776	285,105	197,673	77,247	50,315	2,467,199
1999	44,755	51,657	118,141	155,831	261,931	426,744	515,641	441,791	305,006	200,457	89,799	55,503	2,667,249

Source: Based on NPS data.

\* NPS methods for calculating visitation numbers changed in 1995. This resulted in significant reductions in visitation numbers compared to prior years.

Recreation boating is the largest type of boating activity on Lake Powell, with an estimated 1.5 million boater nights per year (1988 values). Although use at some of the major marinas, such as Wahweap, Hall's Crossing, and Bullfrog, decreased during a low water period in 1989, the total number of boats on Lake Powell was reported to have increased 14.5 percent by July 31, 1989, compared to the same period in 1988 (Reclamation, March 1995). Specific facilities and reservoir elevations important to their operation are discussed in the following sections. Map 3.9-1 depicts Lake Powell and the locations of shoreline facilities.

**Map 3.9-1**  
**Lake Powell and Associated Shoreline Recreation Facilities**



### 3.9.2.2.2 Shoreline Public Use Facilities

The public use facilities at Lake Powell that include water-based recreation activities are Wahweap, Dangling Rope Marina, Halls Crossing, Bullfrog, Hite, and Antelope Point. The GCNRA Proposed General Management Plan (NPS, 1979) describes the estimated capacity and development at these areas; these estimates are based on general concepts only and further detailed planning was proposed to begin after the plan's acceptance in 1979. Table 3.9-2 summarizes the activities at each of the sites, as depicted in the Proposed General Management Plan for Glen Canyon.

Supplemental information, when known, is also indicated on the table and is referenced. If the actual number of improvements (boat slips, mooring buoys, houseboats, etc.) at a facility are known, they are enumerated in Table 3.9-2; otherwise, the presence of an improvement is indicated with a bullet (•). If no information is available, it is denoted with "N/A."

Wahweap – The facilities at Wahweap are the closest to Glen Canyon Dam, located off Interstate 89 at the mouth of Wahweap Bay. According to a study that addressed fluctuating lake levels and recreation use, the Stateline Launching Ramp at Wahweap became inoperable in 1989 when the lake elevation decreased to below 3677 feet msl (Combrink and Collins 1992). In 1993, NPS extended the Wahweap and Stateline boat ramps down to 3612 feet msl during another low water period (Henderson, 2000).

Dangling Rope Marina – The facilities at Dangling Rope Marina were proposed to replace the facilities at Rainbow Marina in Forbidding Canyon. All the facilities float, and they are only accessible by boat (NPS, 1979). In addition to the facilities, tour boats depart from the marina for visits to the Rainbow Bridge National Monument during the recreation season (NPS, 1993). There are no known reservoir surface elevations that may impair operation of this facility.

Halls Crossing – The facilities at Halls Crossing are located off Utah Highway 276 on the east shore of Lake Powell, across the bay from Bullfrog Marina. According to a study that addressed fluctuating lake levels and recreation use, the Halls Crossing Ferry Ramp became inoperable in 1989 when the lake elevation decreased to below 3675 feet msl (Combrink and Collins, 1992). In 1993 NPS extended the boat ramp down to 3612 feet msl during another low water period (Henderson, 2000).

Bullfrog – The facilities at Bullfrog are located midway up Bullfrog Bay, off of Utah Highway 276, across the bay from Halls Crossing. According to a study that addressed fluctuating lake levels and recreation use, the Bullfrog Ferry Ramp became inoperable in 1989 when the lake elevation decreased to below 3675 feet msl. In addition, the Bullfrog Utility Service became inaccessible when the elevation decreased to below 3670 feet msl (road access is also unavailable at the slips) (Combrink and Collins, 1992). In 1993 NPS extended the boat ramp down to 3612 feet msl during another low water period (Henderson, 2000).

**Table 3.9-2  
Lake Powell Shoreline Public Use Facilities**

<b>Facility</b>	<b>Wahweap</b>	<b>Dangling Rope Marina</b>	<b>Halls Crossing</b>	<b>Bullfrog</b>	<b>Hite</b>	<b>Antelope Point (proposed)</b>
Lodging (rooms)	375	N/A	20	56	5	200-225
Restaurant/Snack Bar	2/1	N/A/1	•/1	1/1	N/A	•
Tour boats	9	N/A	N/A	1	N/A	2
Boat slips	870	N/A	165	254	6	250-300
Mooring buoys	180	N/A	141	220	54	N/A
Rental houseboats	175	N/A	89	112	21	60
Rental small boats	150	N/A	44	50	27	60
Dry storage	450	N/A	230	750	109	•
RV park (spaces)	120	N/A	32	24	N/A	150
Marina campstore	1	1	1	1	N/A	1
Store	•	•	1	1	1	1
Boat repair	•	•	•	•	N/A	N/A
Service station	•	•	gas	•	gas	•
Parking (spaces)	2,500	N/A	300	1,575	150	220
Campground (sites)	215	N/A	64	100	6	•
Picnic (sites)	124	N/A	20	50	N/A	N/A
Day use beaches/trails	N/A	N/A	N/A	N/A	N/A	•
Launching ramps	2	N/A	1	1	1	1
Airstrip	N/A	N/A	N/A	3,500- foot, paved	2,100-foot, paved	N/A
Visitor center, cultural center	•	N/A	N/A	N/A	N/A	•
Ranger station	•	N/A	•	•	N/A	•
Employee housing	•	•	•	N/A	•	•
Concessionaire quarters	80	N/A	30	40	10	N/A
Dorm units	119	6	24	96	0	N/A
Capacity (use per day)	7,800- 10,100	2,400- 3,100	3,400- 4,400	7,900- 10,300	2,500- 3,300	N/A

Source: GCNRA 1979. Proposed General Management Plan

• indicates presence of an improvement

N/A not available – indicates specific information unavailable at time of preparation.

**Hite** – The facilities at Hite are located off of Utah Highway 95. According to a study that addressed fluctuating lake levels and recreation use, the Hite Launching Ramp became inoperable in 1989 when the lake elevation decreased to below 3677 feet msl (Combrink and Collins 1992). In 1993 NPS extended the boat ramp down to

3612 feet msl during another low water period. However, the ramp area is known to be useable down to 3630 feet msl (Henderson, 2000).

Antelope Point – The facilities at Antelope Point are located off of Arizona Highway 98 on the southern side of Lake Powell. Antelope Island lies only 2,400 feet msl across a narrow channel of Lake Powell. Data on visitation at Antelope Point have not been collected on a formal basis.

There is one public launching ramp at Antelope Point (NPS, undated) and other facilities are planned or under construction. The proposed facilities are shown on maps in the Development Concept Plan above the water surface elevation of 3680 feet msl. According to the NPS, the boat ramp is operable down to 3670 feet msl without adjustments. Since the facilities have been in operation for only a few years, any adjustments to facilities that would be necessary below 3670 feet msl are unknown.

More recent information from the Navajo Nation indicate that the ramp becomes inoperable when the reservoir elevation is 3677 feet msl, seven feet higher than the 3670 feet msl elevation discussed above.

Rainbow Bridge National Monument – The Rainbow Bridge National Monument is bounded on three sides by the Navajo Reservation in southern Utah near the Utah/Arizona border. The facilities at the monument include courtesy docks, restrooms, a floating walkway, and a floating interpretive platform. Trails from the dock lead to viewing areas, one for when Lake Powell is below the full-pool elevation of 3700 feet msl, and one for high water viewing.

The docks and trail system are designed to accommodate lake level fluctuations allowed in the operation of Glen Canyon Dam and powerplants (from 3490 feet msl to 3700 feet msl) (NPS, 1993). If the lake levels fall below 3650 feet msl, the dock facilities would be moved, and the old land trail through Bridge Canyon (submerged at full pool) would be hardened and used for access. The floating walkway and interpretive platforms would be removed and stored. The courtesy docks would be connected to the land trail with a short walkway (NPS, 1990). Large quantities of silt have been deposited where Bridge Creek flows into Lake Powell that could create access problems at low water surface elevations. The large silt flats are difficult to cross with either floating walkways and may require special construction techniques to bridge these areas. At some lake elevations, it may be infeasible to maintain water access to the monument (NPS, 1993); however, the specific elevation is not known.

When Lake Powell is operated below 3700 feet msl, some of the Rainbow Bridge National Monument is within a high hazard flash flood area. The 100- and 500-year flood elevations in Bridge Creek are estimated to be 7.5 feet and 10 feet above the channel, respectively. For the areas above the lake, the trail follows the creek and is outside the 100- and 500-year floodplains. The transition zone along the lake's edge could be subject to some water surface elevation increase, surface turbulence, and

significant velocities, depending on lake elevation and flood magnitude. For the lake itself, there would be little or no discernable water surface increase and the turbulence would be limited. When Lake Powell is at full operating pool, flash flood areas are in the Bridge Creek Canyon drainage, outside the monument.

The General Management Plan for Rainbow Bridge includes a Flash Flood Mitigation Plan. In the event of combined low pool elevations and flash flood conditions, there are four components of the mitigation plan that would be put in to place. These components include: 1) wayside exhibit with information for visitors to inform them of possible flash flood hazards; 2) additional signage in the flood hazard zones to alert visitors where to move in case of a flood; 3) identification of evacuation and emergency measures, including chain of command responsibilities, emergency supply locations, and support facilities; and 4) installation of a warning system that will alert visitors to evacuate.

Prior to the construction of Glen Canyon Dam, access to the area was primarily by foot. Since the creation of Lake Powell, access is now primarily by water, however the area is also accessible by trails through Navajo Mountain. Access to the monument is restricted during the recreation season in accordance with the monument's carrying capacity of 200 people at one time. In addition, access is limited daily during certain times of the day. Boat tours to the monument are allowed during the busier time of the day and originate at Dangling Rock Marina. All tours have an NPS interpreter on board to convey the monument's significance. Access during quieter times of the day is limited to 5 to 8 private boats. During the off-season, access to the monument is unrestricted except that the boat tours are managed to ensure that only one tour boat at a time is present at the monument (NPS, 1993).

#### **3.9.2.2.1 Threshold Elevations**

From the information presented above on reservoir pool elevations, two elevations, 3670 feet msl and 3612 feet msl, were identified as representative thresholds below which shoreline facilities at Lake Powell could be affected by declines in pool elevation.

Several of the facility descriptions presented above identified operational difficulties associated with boat ramps occurring at elevations between 3670 feet msl and 3677 feet msl. This information came from a 1992 study conducted by Combrink and Collins. In addition, the Navajo Nation identified elevations below 3677 feet msl as an operational constraint to the boat ramp at Antelope Point. However, this specific elevation was not identified as a threshold elevation for assessing the effects of the interim surplus criteria alternatives for the following reasons. First, all of the boat ramps that were initially identified as having constraints below 3677 feet msl were subsequently extended down to 3612 feet msl, making this elevation a more applicable threshold. Also, the Antelope Point boat ramp was not in operation at the time of, and was therefore not included in, the Combrink and Collins study. Two elevations were

identified as problematic for the Antelope Point boat ramp: 3677 feet msl by the Navajo Nation and 3670 feet msl by the NPS. Since these elevations are relatively similar, one, 3670 feet msl, was selected as a threshold elevation for the analysis in this DEIS. The analysis of probabilities associated with reservoir declines below the 3670 feet msl threshold elevation can be used to extrapolate probabilities associated with 3677 feet msl.

As discussed above, the boat ramps at Wahweap, Halls Crossing, Bullfrog, and Hite are now designed to operate down to 3612 feet msl, below which it is not known what adjustments and capital improvement costs could be required. Therefore, 3612 feet msl is used in this analysis for a second threshold elevation for marinas and boat ramps at Lake Powell.

These threshold elevations of 3670 feet msl and 3612 feet msl are used to evaluate the effects of the baseline condition and interim surplus criteria alternatives on shoreline facilities at Lake Powell in the Environmental Consequences section (Section 3.9.2.3.1)

### **3.9.2.2.3 Lake Mead Recreation Resources**

Lake Mead, the reservoir created by the construction of Hoover Dam, is located in the Lake Mead National Recreation Area (LMNRA) in southern Nevada and northern Arizona. The LMNRA contains 1.5 million acres and encompasses the 100-mile-long Lake Mead, 67-mile-long Lake Mohave, the surrounding desert, and the isolated Shivwits Plateau in Arizona. At an elevation of 1210 feet msl, Lake Mead's surface area is 153,235 acres, the storage capacity is 25.9 maf, and there are 695 miles of shoreline (Reclamation, August 1996). Lake Mead is the largest man-made lake in the Western Hemisphere.

LMNRA receives approximately ten million visitors annually. Typical water-based recreation activities that occur on Lake Mead include swimming, boating, houseboating, fishing, sailboarding, paddlecraft use, and scuba diving (Reclamation, August 1996). In addition, the majority of the boats on average are personal watercraft, and there may be as many as 6,000 boats combined on Lake Mead and Lake Mohave during a peak recreation use weekend. At Boulder Beach, which is a more urbanized area (near Las Vegas) of the LMNRA, the personal watercraft percentage may be as high as 50 percent.

### **3.9.2.2.4 Shoreline Public Use Facilities at Lake Mead**

Six marinas at Lake Mead provide boat launching facilities as well as slips and storage, fuel, and boat launches. In addition, there are three boat ramps without associated marinas on Lake Mead. The marinas include Boulder Beach, Las Vegas Bay, Calville Bay, Echo Bay, Overton Beach and Temple Bar. The boat ramps are located at Hemenway, Government Wash and South Cove. These six marinas are

summarized in Table 3.9-3, and all the public facilities are described below. If the actual number of improvements (boat slips, etc.) at the facility is known, it is included in the table; otherwise, the presence of an improvement is indicated with a bullet (•). If there are no facilities at a location, this is indicated with an “N/A” for “not applicable.” Map 3.9-2 shows the locations of these facilities.

**Table 3.9-3**  
**Lake Mead Marina Public Use Facilities**

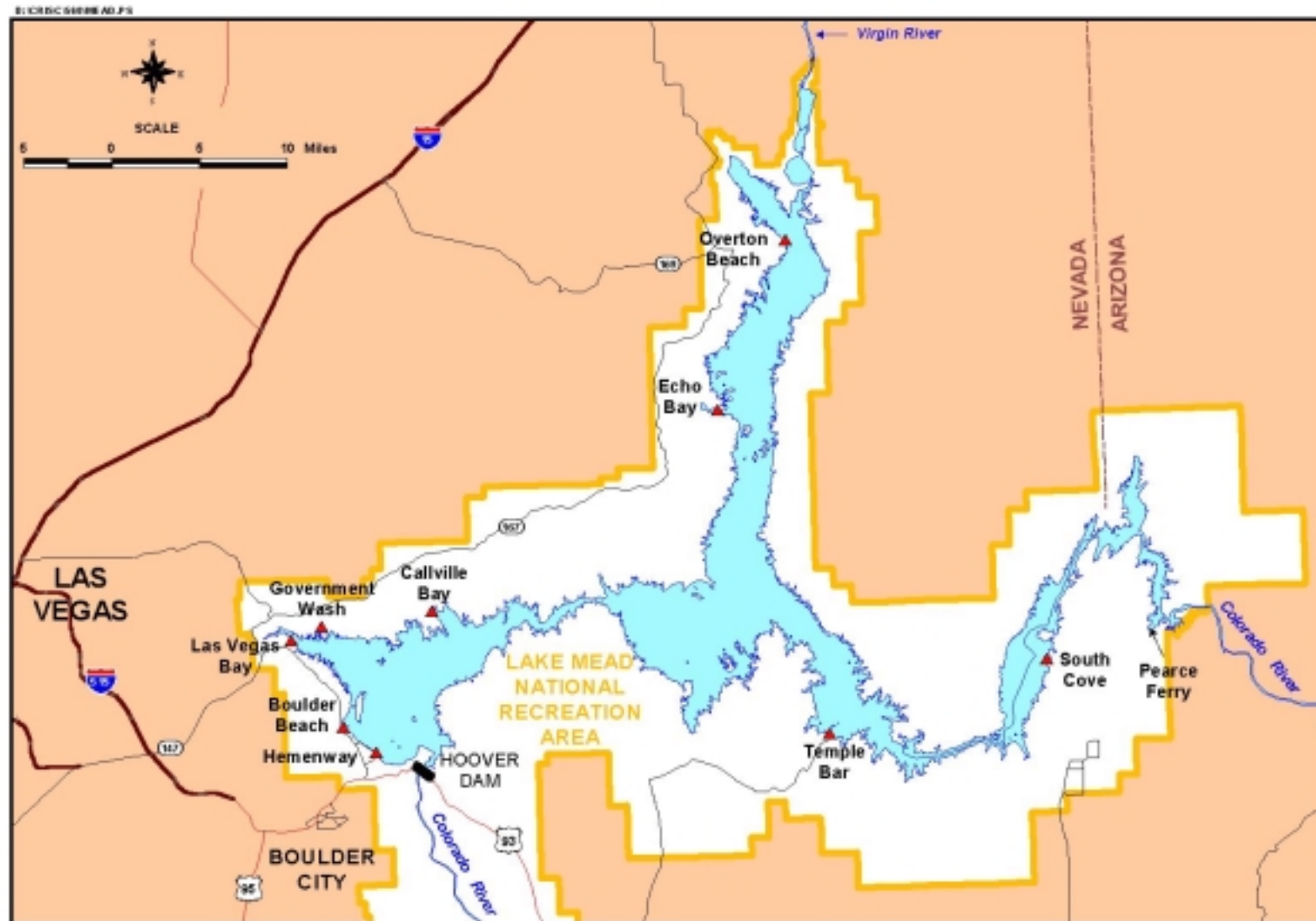
Facility	Boulder Beach/ Lake Mead Marina	Las Vegas Bay	Calville Bay	Echo Bay	Overton Beach	Temple Bar
Lodging	•	N/A	N/A	•	N/A	•
Restaurant	•	•	•	•	•	•
Tour boats	•	N/A	N/A	N/A	N/A	N/A
Marina (boat slips)	750	•	650	320	•	•
Mooring buoys	N/A	N/A	N/A	N/A	N/A	N/A
Rental houseboats	N/A	N/A	•	•	N/A	N/A
Rental small boats	•	N/A	N/A	•	N/A	•
Dry storage	•	•	•	•	•	•
RV Park (spaces)	N/A	N/A	N/A	58	N/A	7
Trailer village	•	N/A	•	69	•	111
Trailer sewage dump	•	N/A	•	•	•	•
Grocery/gift store	•	•	•	•	•	•
Gasoline/Propane	•	N/A	•	•	•	•
Boat sewage dump	•	•	•	•	•	•
Parking (spaces)	N/A	N/A	N/A	N/A	N/A	N/A
Campground (sites)	154	89	80	166	N/A	153
Picnic (sites)	•	•	•	N/A	N/A	N/A
Showers	•	N/A	•	•	•	•
Launching ramps	•	•	•	•	•	•
Airstrip	N/A	N/A	N/A	•	N/A	•
Ranger station	•	•	•	•	•	•
Self-service laundry	•	N/A	•	•	•	•
Capacity (use per day)	N/A	N/A	N/A	N/A	N/A	N/A

Source: NPS, 1995

• indicates presence of an improvement

N/A information not available

Map 3.9-2  
Lake Mead and Associated Shoreline Recreation Facilities



Recreation boating is very popular at Lake Mead, and the shoreline public use facilities are associated with boating use. Most of the facilities shown in the table above were designed to operate at full pool. However, NPS has determined costs associated with adjusting facilities based on lowered lake elevations. These facilities are out of their normal operating range at pool elevations of 1180 feet msl, requiring sizable capital expenditures to restore them to working order. In addition, there are additional costs associated with any 20-foot drop below this level.

Hemenway – The boat ramp facility at Hemenway is the closest to Hoover Dam and is located off Nevada Highway 166. There is one courtesy dock and a parking area (Henderson, 2000). In addition, campgrounds and a group campground are located at Hemenway. The group campground is for self-contained vehicles, such as trailers and motor homes. There are no restrooms or tables.

Boulder Beach – The facilities at Boulder Beach are located off of Lakeshore Scenic Drive, just off of Nevada Highway 167 outside of Boulder City, Nevada, and include restrooms, tables and grills. In addition to these above facilities, there is a group campground at Boulder Beach for tent camping only with limited vehicle parking.

Las Vegas Bay – The facilities at Las Vegas Bay are located off Lakeshore Scenic Drive, just off Lake Mead Drive (Nevada Highway 167). According to a marina worker, when the lake elevation drops below 1190 feet msl, the boat ramps and floats would have to be readjusted.

Government Wash – The boat ramp facility at Government Wash is located off Nevada Highway 167. There is one courtesy dock and a parking area (Henderson, 2000).

Calville Bay – The facilities at Calville Bay are located off Nevada Highway 167 on the north shore of Lake Mead, midway up Callville Bay.

Echo Bay – The facilities at Echo Bay are located off Nevada Highway 167, midway up Overton Arm.

Overton Beach – The facilities at Overton Beach are located off Nevada Highway 169, near the top of Overton Arm.

South Cove – The boat launching facilities at South Cove are located off Aztec Wash, which is off Interstate 93 in Arizona. There is one courtesy dock, picnic facilities, and unpaved parking (Henderson, 2000). In addition, there is an airstrip approximately four miles from the facilities at South Cove (Henderson, 2000).

Temple Bar – The facilities at Temple Bar are located on the south shore of Lake Mead at the end of an unnamed road off Interstate 93 in Arizona.

#### **3.9.2.2.4.1 Threshold Elevations**

As discussed above, the facilities at Lake Mead are out of their normal operating range at pool elevations 1180 feet msl and below. At 1180 feet msl, sizable capital expenditures to restore the facilities to working order are required. Therefore, 1180 feet msl is identified as the threshold elevation for shoreline facilities at Lake Mead and is used to evaluate the effects of the baseline condition and interim surplus criteria alternatives on shoreline facilities at Lake Mead in the Environmental Consequences section (Section 3.9.2.3.2).

#### **3.9.2.3 ENVIRONMENTAL CONSEQUENCES**

Recreational boating on Lake Mead and Lake Powell is dependent upon access to the water via public shoreline facilities such as marinas, docks, buoys and launch ramps. Some fluctuation in water level is a normal function of reservoir operations, and facilities are designed and operated to accommodate it. However, decreased pool elevations or increased variations or rates in pool elevation fluctuation could result in increased operation costs, facility improvements, temporary closures, or possibly permanent closure of shoreline facilities.

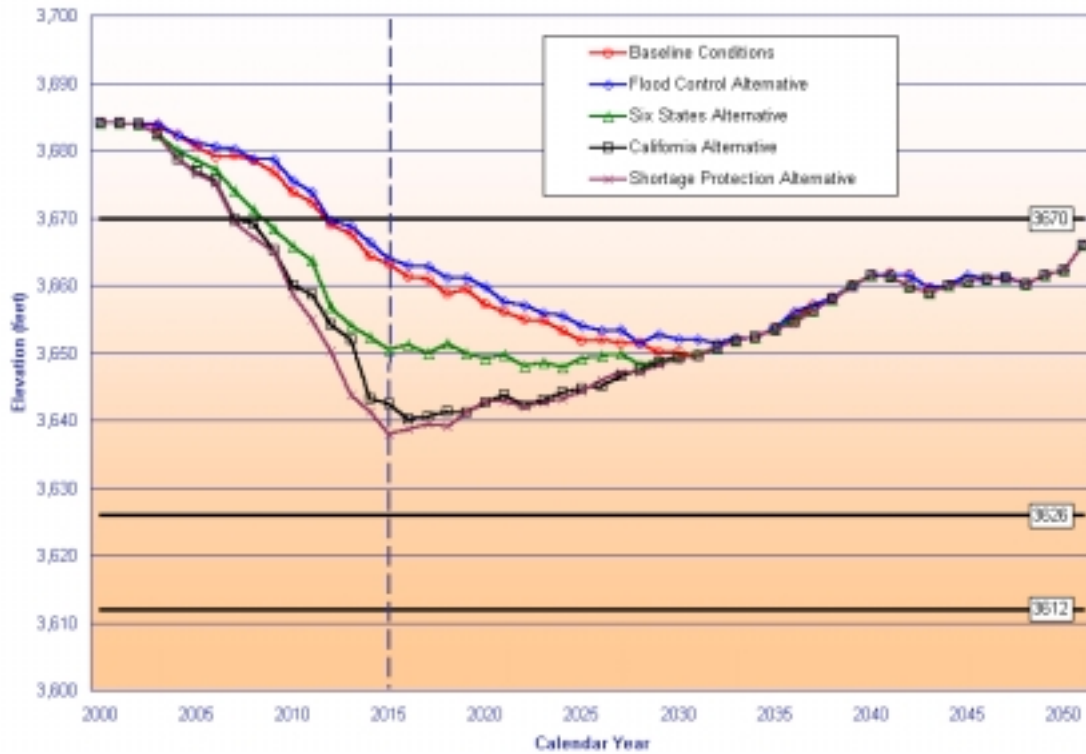
As lake levels fluctuate, facilities must be adjusted accordingly. This could require moving and relocating docks, extending utility lines associated with shoreline facilities, increasing sewage pump capacity, reducing pressure on water supply lines to boats, adjusting and relocating buoys, moving breakwater barriers and channel markers, and extending launch and dock ramps (Combrink and Collins, 1992). If lake fluctuations exceed 25 feet, special adjustments to lake facilities would be necessary, including the relocation of anchors and the extension or reduction of utility lines and cables that provide utility service to floating facilities (Combrink and Collins, 1992).

In addition, if facilities are temporarily or permanently closed or relocated, there may be associated increases in reservoir boating congestion or longer wait times at launch sites that remain open. This could have an effect on boating and boat fishing satisfaction. The cost of relocating facilities in response to changes in reservoir pool elevations is discussed in Section 3.9.6.

##### **3.9.2.3.1 Lake Powell**

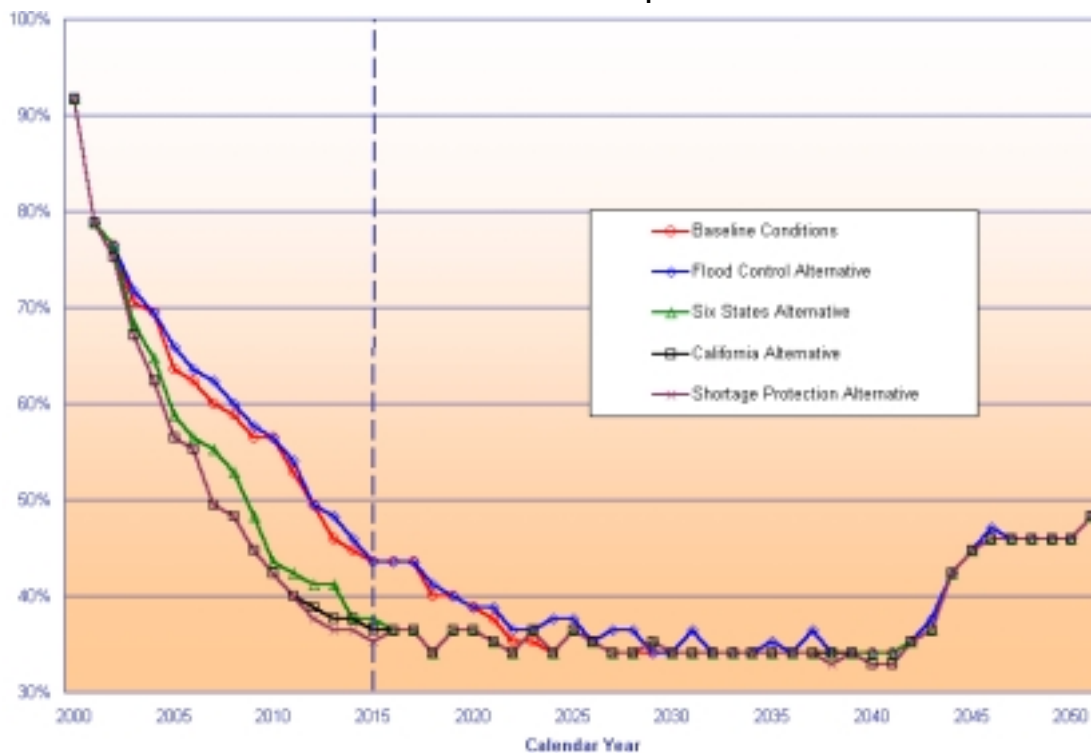
As discussed in the Affected Environment section above, pool elevations of 3670 feet msl and 3612 feet msl were identified as representative thresholds that are problematic for shoreline facilities at Lake Powell. NPS identified elevation 3670 feet msl as important for Antelope Point, and 3612 feet msl for several other facilities, as the elevations below which facility adjustments or capital improvements would be required. Figure 3.9-1 shows projected elevations for baseline conditions and the alternatives over the projected 50-year period, based on a median (50<sup>th</sup> percentile) ranking of system model output.

**Figure 3.9-1**  
**Lake Powell End of Year Water Elevations**  
**Comparison of Surplus Alternatives to Baseline Conditions**  
**50th Percentile Values**



The probability of Lake Powell remaining above 3670 feet msl decreases over the initial 15 years of analyses under baseline conditions and each of the alternatives. Following year 2040, the probability that lake elevations would not go below 3670 feet msl increases by year 2050. Flood Control Alternative projections are least likely to result in pool elevations of below 3670 feet msl, whereas, the Shortage Protection Alternative is most likely. The California and Six States alternatives have probabilities between baseline conditions and the Shortage Protection Alternative. A graph indicating the probability of Lake Powell remaining above 3670 feet msl occurring under baseline conditions and each alternative is shown in Figure 3.9-2. Table 3.9-4 lists probabilities of Lake Powell remaining above 3670 feet msl under baseline conditions and the alternatives.

**Figure 3.9-2**  
**Lake Powell End-of-Year Data Water Elevations**  
**Comparison of Surplus Alternatives to Baseline Conditions**  
**Percent of Values Greater than or Equal to 3670 Feet msl**

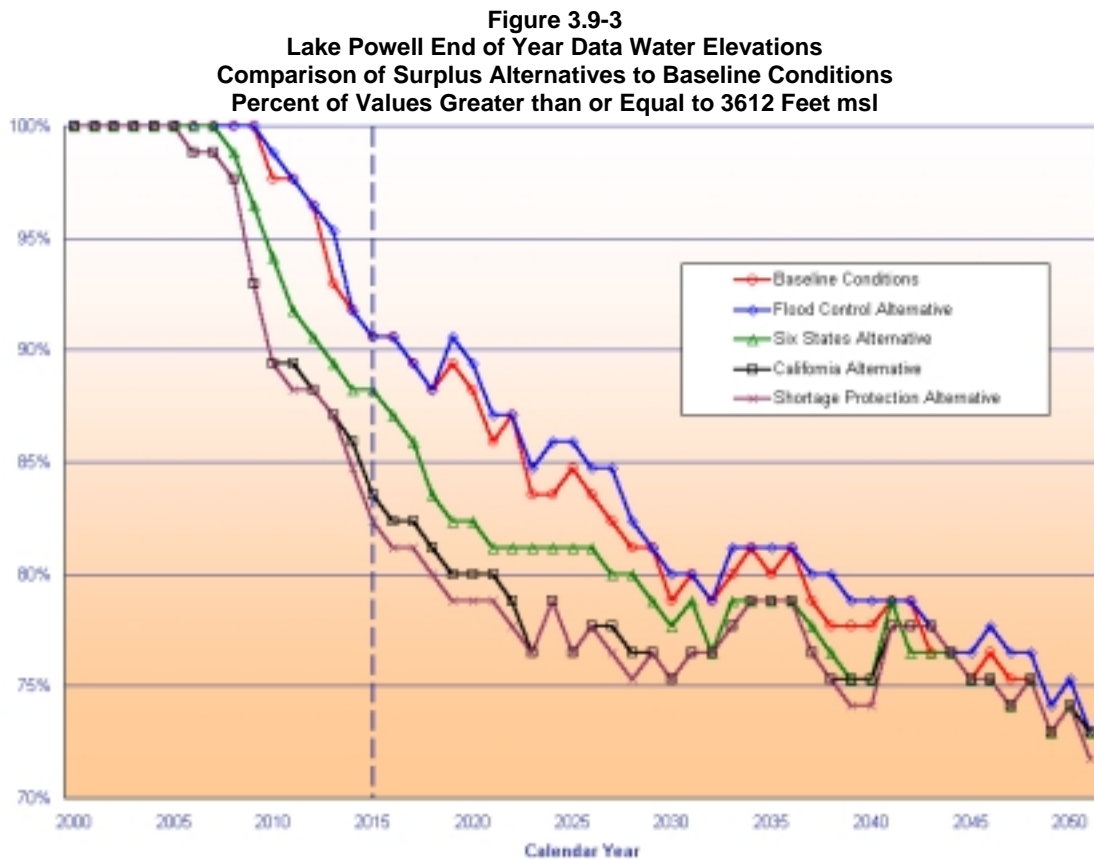


**Table 3.9-4**  
**Comparison of Lake Powell Avoidance Probabilities of Elevation 3670 Feet**

Alternative	Probability of Avoidance of Lake Powell Surface Elevation of 3670 Feet			
	Year 15	Years 16 - 24	Years 25 - 40	Year 50
Baseline Conditions	44%	44%-35%	35%	47%
Flood Control Alternative	44%	44%-36%	36%	47%
Six States Alternative	36%	36%-34%	35%	47%
California Alternative	36%	36%-34%	35%	47%
Shortage Protection Alternative	35%	35%-34%	35%	47%

With regard to the threshold elevation of 3670 feet msl, the modeling indicates that the probability of Lake Powell remaining above this threshold decreases from 100 to as much as 35 percent over the initial 15-year period. Following year 2040, the probability that lake elevations would not fall below this threshold increases and reaches approximately 47 percent by year 2050. The probability of Lake Powell remaining above 3612 feet msl under baseline conditions and each of the alternatives

is shown in Figure 3.9-3. Table 3.9-5 lists the probabilities of Lake Powell remaining above 3612 feet msl under baseline conditions and the alternatives.



**Table 3.9-5**  
**Comparison of Lake Powell Avoidance Probabilities of Elevation 3612 Feet**

Alternative	Probability of Avoidance of Lake Powell Surface Elevation of 3612 Feet	
	Year 15	Years 16-50
Baseline Conditions	91%	91%-75%
Flood Control Alternative	91%	91%-75%
Six States Alternative	88%	88%-73%
California Alternative	83%	83%-75%
Storage Protection Alternative	81%	81%-74%

With regard to the threshold elevation of 3612 feet msl, the modeling indicates that there is at least a 75 percent probability that Lake Powell will remain at or above 3612 feet msl throughout the 50-year period under baseline conditions and all

alternatives. Baseline conditions and the Flood Control Alternative would be similar and have the highest probability of avoiding 3612 feet msl as compared to the other alternatives. The Shortage Protection Alternative would have the lowest probability of avoiding 3612 feet msl, with the Six States and California alternatives lying between the Shortage Protection Alternative and baseline conditions. Each of the alternatives is discussed below with respect to the patterns indicated on Figures 3.9-2 and 3.9-3.

#### **3.9.2.3.1.1 Baseline Conditions**

Lake Powell pool elevations would tend to decline less under the baseline conditions as compared to three of the four other alternatives. At year 2015, the probability that the baseline condition would not go below 3670 feet msl is 44 percent as shown on Table 3.9-4. From year 2016 to 2040, the probability that pool elevations would not fall below 3670 feet msl decreases from 44 to 35 percent, and remains at 35 percent from 2025 to 2040. At year 2040, there is a higher probability that pool elevations would not fall below 3670 feet msl. By 2050 there is a 47 percent probability that reservoir elevations would be at or above 3670 feet msl. The declining trend of all lines (baseline conditions and alternatives) indicates that the decline in Lake Powell elevations can be mostly attributed to increased consumptive use of Colorado River water in the Upper Basin over time.

The facilities at Rainbow Bridge were designed to remain operable at the full operating range of Lake Powell (3700 feet msl to 3490 feet msl). However, facilities at the monument would be affected by pool elevations of 3650 feet msl, as described in the Affected Environment section. At elevations below 3650 feet msl, the dock facilities would be moved, and the old land trail through Bridge Canyon (submerged at full pool) would be hardened and used for access. The floating walkway and interpretive platforms would be removed and stored. The courtesy docks would be connected to the land trail with a short walkway.

Although specific probabilities of avoidance for elevation 3650 feet msl were not determined, the probabilities under baseline conditions that lake elevations would not fall below 3650 feet msl would be similar but slightly lower than the probabilities associated with 3670 feet msl, as discussed above.

When reservoir elevations fall below full pool, there are some areas of the Rainbow Bridge National Monument that are within a flash flood, high hazard area. To mitigate the impacts of these events occurring, the General Management Plan for Rainbow Bridge includes a Flash Flood Mitigation Plan as discussed in Section 3.9.2.2.2.

Under baseline conditions there is a high probability that reservoir elevations will be above 3612 feet msl throughout the 50-year period. Between years 1 and 15, there will be about a 10 percent decline in probability of avoiding elevations below 3612 feet msl, from 100 percent to 91 percent. Between years 16 and 50, the

probability of avoiding 3612 feet msl will continue to decline gradually from 91 percent to about 75 percent.

#### **3.9.2.3.1.2 Flood Control Alternative**

The probability of Lake Powell pool elevations declining under the Flood Control Alternative would be approximately the same as baseline conditions. At year 2015, the probability that the Flood Control Alternative would not go below 3670 feet msl is 44 percent, as shown in Table 3.9-4. From year 2016 to 2040, the probability of avoidance decreases from 44 to 36 percent, reaching 36 percent between years 2025 and 2040. By year 2050, the probability of avoidance rises to 47 percent.

Probabilities of lake levels declining below 3650 feet msl under the Flood Control Alternative (important for facilities at Rainbow Bridge) are similar to, but slightly lower than those associated with 3670 feet msl as discussed above.

The probability of avoiding reservoir pool elevation 3612 feet msl under the Flood Control Alternative would be similar to those described under baseline conditions.

#### **3.9.2.3.1.3 Six States Alternative**

The probability of Lake Powell pool elevations declining under the Six States Alternative would increase by about 15 percent at the most, compared to baseline conditions. In general, pool elevations would tend to begin decreasing approximately 5 years sooner than under baseline conditions. At year 2015, the probability that reservoir levels would go below 3670 feet msl is 36 percent as shown in Table 3.9-4. From year 2016 to 2040, the probability of avoidance decreases from 36 to 34 percent, reaching 35 percent between years 2025 and 2040. By year 2050, the probability of avoidance increases to 47 percent.

Probabilities under the Six States Alternative of lake levels declining below 3650 feet msl (important for facilities at Rainbow Bridge) are similar, but slightly lower, than those associated with 3670 feet msl as discussed above.

The probability of avoiding reservoir elevation 3612 feet msl would be slightly lower under the Six State Alternative as compared to baseline conditions. Between years 1 and 15, the probability of avoidance would decrease from 100 percent to 88 percent as compared to 91 under baseline conditions. Between years 16 and 50, the probability of avoidance would decline more rapidly, reaching the lowest probability of all the alternatives (73 percent) by year 2050.

#### **3.9.2.3.1.4 California Alternative**

The probability of Lake Powell pool elevations declining under the California Alternative would increase by about 10 percent compared to baseline conditions.

Under the California Alternative, pool elevation recession would be more likely to occur 6 to 8 years sooner than under baseline conditions. At year 2015, the probability of avoidance is 36 percent, as shown in Table 3.9-4. From year 2016 to 2040, the probability of Lake Powell elevations declining below 3670 feet msl decreases from 36 to 34 percent, reaching 35 percent between year 2025 and 2040. By year 2050, the probability of avoidance begins to rise and reaches 47 percent at year 2050.

Probabilities under the California Alternative of lake levels declining below 3650 feet msl (important for facilities at Rainbow Bridge) are similar, but slightly lower, than those associated with 3670 feet msl as discussed above.

The probability of avoiding reservoir elevation 3612 feet msl would be about 10 percent lower under the California Alternative compared to baseline conditions. Between years 1 and 15, the probability of avoidance would decrease from 100 percent to 83 percent. Between years 16 and 50, the probability of avoidance would decline more rapidly; reaching 75 percent by 2050.

#### **3.9.2.3.1.5 Shortage Protection Alternative**

Lake Powell pool elevations would have a higher probability of declining under the Shortage Protection Alternative as compared to projections of baseline conditions and the other alternatives. Under the Shortage Protection Alternative, pool elevation recession would be more likely to occur 10 years sooner than under baseline conditions. At year 2015, the probability that Lake Powell surface elevations under the Shortage Protection Alternative would not decline below 3670 feet msl is 35 percent, as shown on Table 3.9-4. From year 2016 to 2040, the probability of avoidance decreases from 35 to 34 percent, reaching 35 percent between year 2025 and 2040. By year 2050, the probability of avoidance reaches 47 percent.

Probabilities of under the Shortage Protection Alternative of lake levels declining below 3650 feet msl (important for facilities at Rainbow Bridge) are slightly lower than those associated with 3670 feet msl discussed above.

Under the Shortage Protection Alternative, the probability of avoiding elevation 3612 feet msl would be the lowest, 81 percent by year 2015, as compared to the other alternatives and baseline conditions. In addition, the probability of lower pool elevations under this alternative would tend to occur anywhere from one to 10 years sooner than they would under the other alternatives.

#### **3.9.2.3.2 Lake Mead**

As discussed in the Affected Environment section above, a pool elevation of 1180 feet msl was identified as a representative threshold that is problematic for shoreline facilities at Lake Mead. NPS provided information that indicates when Lake Mead is at or drops below 1180 feet msl adjustments need to be made to the major facilities.

In addition to costs associated with adjusting facilities to 1180 feet msl, there are additional costs associated with declines below elevation 1180 feet msl. Figure 3.9-4 shows projected elevations for the alternatives over the projected 50-year period, based on median elevations provided by system modeling and data processing. A graph of the probability of avoiding pool elevations below 1180 feet msl for baseline conditions and each of the alternatives is shown in Figure 3.9-5.

Baseline conditions and projections for each of the alternatives are discussed below with respect to the information indicated on Figure 3.9-2. The time periods of 1 to 15 years and 16 to 50 years are described under each alternative. Table 3.9-6 summarizes probabilities of Lake Mead dropping below 1180 feet msl for baseline conditions and the alternatives.

**Table 3.9-6**  
**Comparison of Lake Mead Elevation Avoidance Probabilities for Elevation 1180 Feet**

Alternative	Probability of Avoidance			
	Year 15	Years 16 - 40	Years 25 - 40	Year 50
Baseline Conditions	44%	44%-35%	35%	34%
Flood Control Alternative	45%	45%-38%	37%	36%
Six States Alternative	38%	38%-35%	35%	35%
California Alternative	34%	34%-35%	35%	34%
Shortage Protection Alternative	34%	34%-35%	35%	34%

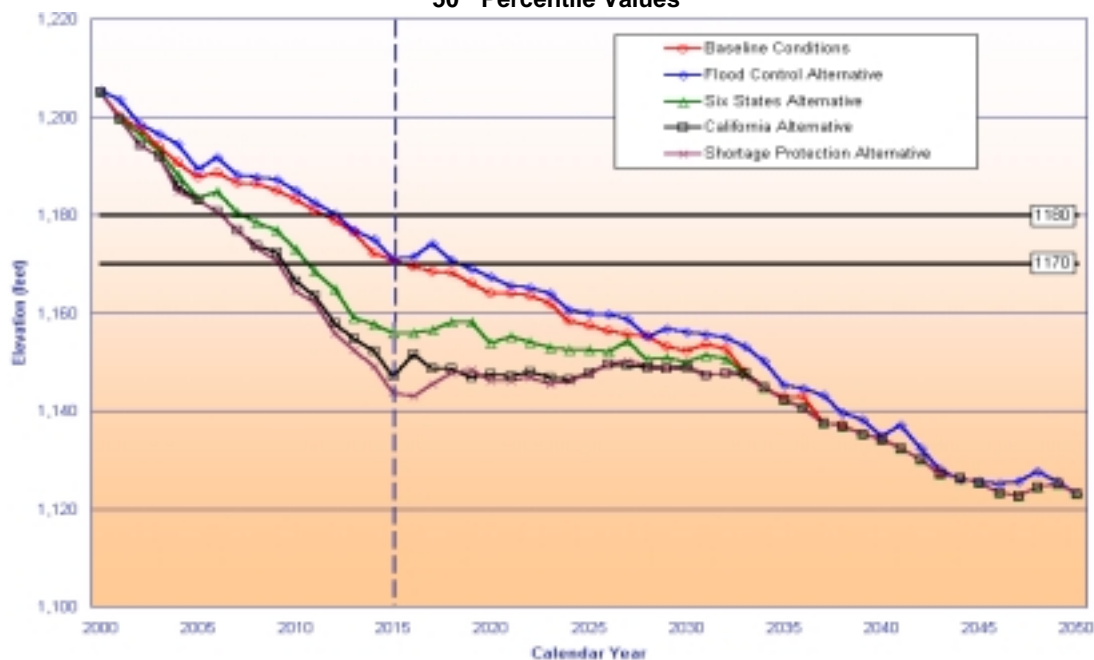
### **3.9.2.3.2.1 Baseline Conditions**

Modeling results indicate the potential for Lake Mead pool elevations to decline the least under the baseline conditions as compared to three of the four other alternatives. At year 2015, the probability that Lake Mead elevations under baseline projections would not decline below 1180 feet msl is 44 percent, as shown on Table 3.9-6. From years 2016 through 2050, the probability of avoidance decreases from 44 to approximately 34 percent, leveling at 35 percent between years 2025 and 2040. The decline in Lake Mead elevations under baseline conditions can be attributed to increases in upper basin uses over time.

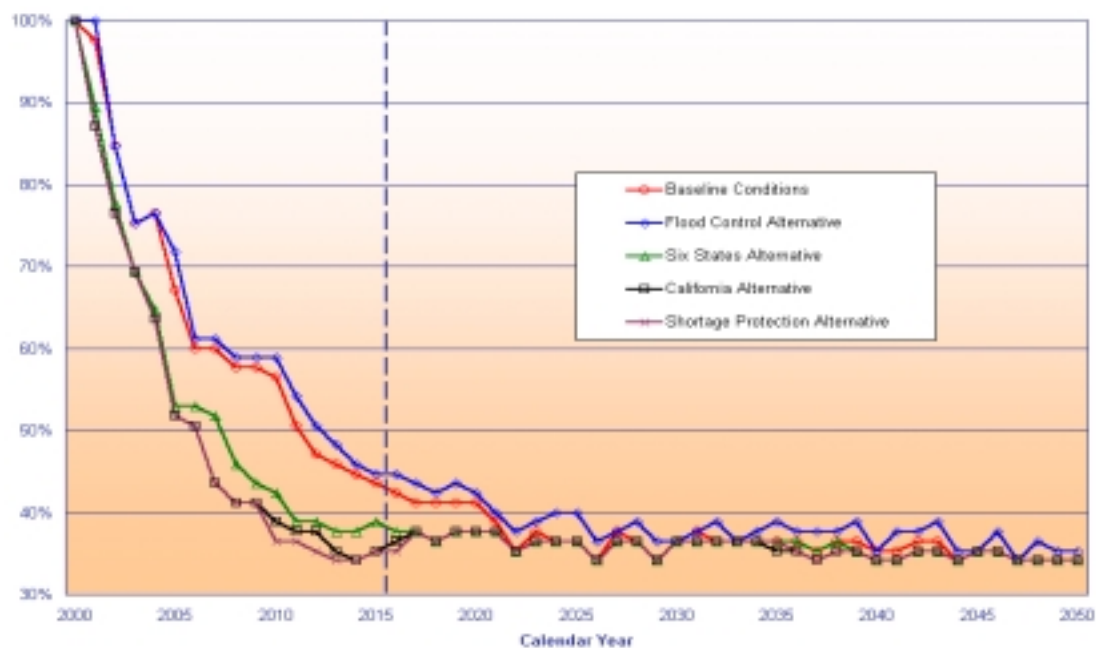
### **3.9.2.3.2.2 Flood Control Alternative**

The probability of Lake Mead pool elevations receding under the Flood Control Alternative would be slightly lower than baseline conditions. At year 2015, the probability that Lake Mead elevations under the Flood Control Alternative would not decline below 1180 feet msl is 45 percent, as shown in Table 3.9-6. From years 2016 through 2050, the probability of avoidance decreases from 45 to approximately 36 percent, leveling at 37 percent between years 2025 and 2040.

**Figure 3.9-4**  
**Lake Mead End-of-Year Data Water Elevations**  
**Comparison of Surplus Alternative to Baseline Conditions**  
**50<sup>th</sup> Percentile Values**



**Figure 3.9-5**  
**Lake Mead End-of-Year Data Water Elevations**  
**Comparison of Surplus Alternatives to Baseline Conditions**  
**Percentage of Values Greater Than or Equal to 1180 Feet**



### **3.9.2.3.2.3 Six States Alternative**

The probability of Lake Mead pool elevations receding under the Six States Alternative would increase by approximately 10 percent as compared to baseline conditions. In general, the recession of pool elevations would tend to occur between 5 and 10 years sooner than under baseline conditions. At year 2015, the probability that Lake Mead elevations under the Six States Alternative would not decline below 1180 feet msl is 38 percent. From years 2016 through 2050, the probability of avoidance decreases from 38 to approximately 35 percent, leveling at 35 percent between years 2025 and 2040.

### **3.9.2.3.2.4 California Alternative**

The probability of Lake Mead pool elevations receding under the California Alternative is very similar to the Six States Alternative. Under the California Alternative, pool elevation recession would be more likely to occur 6 to 13 years sooner than under baseline conditions. At year 2015, the probability of avoidance is 34 percent. From years 2016 through 2050, the probability of avoidance remains relatively constant at approximately 34 percent.

### **3.9.2.3.2.5 Shortage Protection Alternative**

Lake Mead pool elevations would have a higher probability of declining under the Shortage Protection Alternative as compared to projections of baseline conditions and the other alternatives. The difference of probabilities between the Shortage Protection Alternative and baseline conditions could be as much as a 25 percent. In addition, the recession in pool elevations would occur from 2 to 15 years sooner between the Shortage Protection Alternative and baseline conditions. At year 2015, the probability that Lake Mead under the Shortage Protection Alternative would not decline below 1180 feet msl is 34 percent. From years 2016 through 2025, the probability of avoidance increases slightly from 34 to approximately 35 percent, leveling at 35 percent between years 2025 to 2040, then decreasing to 34 percent in year 2050.

## **3.9.3 RESERVOIR BOATING/NAVIGATION**

This section discusses potential effects of the interim surplus criteria on reservoir boating and navigation. This includes a discussion of areas on the reservoir that could become unsafe for boating at certain elevations due to exposed rocks or other obstructions, and safe boating densities which indicate the number of boats that can safely be accommodated on the reservoirs at one time.

Boating navigation and safe boating densities on Lake Powell and Lake Mead are dependent upon water surface elevations. As lake levels decline, so do the available surface area. Hazards such as exposed rocks may become more evident or changes in navigation patterns may be necessary. The area of the reservoirs available for boating

is also reduced, which may affect the number of boats that can safely operate at one time. At low pool elevations, special buoys or markers must be placed to warn boaters of navigational hazards. In addition, signs may be placed in areas that are deemed unsuitable for navigation.

### **3.9.3.1 METHODOLOGY**

Description of the affected environment is based on a literature review of published and unpublished documents and maps, and personal communications with NPS staff at the GCNRA and LMNRA. Information included the identification of navigation issues associated with recreational boating on Lake Powell and Lake Mead, including navigation safety and safe boating densities. Low reservoir pool elevations identified in the literature as being of concern for reservoir boating and navigation are discussed. Assessment of environmental consequences associated with implementing the interim surplus criteria alternatives is based on a probability analysis of exceeding identified threshold pool elevations.

Safe boating capacity is another aspect of boating navigation and safety. Safe boating is one factor that can be used to assess the carrying capacity of a reservoir. To date, no determination of carrying capacity has been made for either Lake Powell or Lake Mead. However, the NPS is currently developing a carrying capacity approach for managing water-based recreation on Lake Mead that is based on the U.S. Forest Service Recreation Opportunity Spectrum system.

A safe boating density of 9 acres per boat was established by the GCNRA (Reclamation, March 1995) for Lake Powell. The 9 acres per boat could be used to assess the effects of the interim surplus criteria alternatives on boating safety if daily boating levels for the reservoirs were available. However, there is no known information on the level of daily or peak boating use, such as whether the current boating densities on the reservoirs have approached or exceeded safe boating densities based on a standard of 9 acres per boat (as discussed below). Without information on current reservoir boat densities, it is not known whether reductions in pool elevations in the future would result in unsafe boating conditions.

### **3.9.3.2 AFFECTED ENVIRONMENT**

#### **3.9.3.2.1 Lake Powell Boating Navigation and Safety**

In 1986, the GCNRA developed an “Aids to Navigation Plan” for Lake Powell that identified safety boating issues on the reservoir and low pool elevations that can affect boating (GCNRA, 1986). The navigation system uses regulatory buoys and other marking devices to warn boat operators of hazardous conditions associated with subsurface obstructions or changes in subsurface conditions that could be hazardous for safe passage. Placement of many of these marking devices is dependent on the lake elevation.

At pool elevations below 3680 feet msl, there are several places where buoys are placed for safe navigation, but remain passable. However, at elevation 3626 feet msl and 3620 feet msl there are two areas on the reservoir that are closed to commercial tour boats and recreational boats, respectively, because of hazardous obstructions to navigation. One of the areas is around Castle Rock, just east of Wahweap Marina, and the other is around Gregory Butte, which is about midway to Dangling Marina from Wahweap (as shown previously on Map 3.9-1). At elevation 3626 feet msl commercial tour boats leaving the Wahweap Marina, headed up reservoir (east), must detour 8.5 miles around the southern end of Antelope Island. At Gregory Butte, commercial tour boats must detour 4.5 miles around Padre and Gregory Buttes (GCNRA, 1986). The added mileage and increased travel time makes the more popular half-day trips of the area infeasible for commercial tour boat operators. In addition, the added mileage may influence recreational boaters to stay in the Wahweap Bay area which can result in congestion (Henderson, 2000).

In addition to buoys marking obstructions, the Aids to Navigation Plan also established a marked travel corridor to guide boat travel on Lake Powell. This primary travel corridor is the main channel of the old Colorado River bed which is marked with buoys along the entire length of the reservoir. Except for the reservoir mouth, there are no known pool elevations at which boat passage along this main travel corridor becomes restricted and affects boating.

Near the reservoir mouth, where the San Juan meets the Colorado River, a delta has formed that can affect river boaters coming down the San Juan into Lake Powell at low pool elevations. River boaters from the San Juan River paddle through Lake Powell to a location where a boat transports the whitewater boaters the remaining 20 to 25 miles (depending on the pick-up location) to the Hite Marina. At low water surface elevations, the river runners travel further downstream to reach a location that is accessible to the boater transport company boat. Although this results in more miles to paddle to the takeout, there is usually enough current in the river to carry the boats. However, the added mileage can expose the boaters to additional navigational hazards and require portaging of boats due to restricted channel widths and subsurface conditions. Table 3.9-7 summarizes the elevations that are critical for boating navigation on Lake Powell.

**Table 3.9-7**  
**Lake Powell Important Elevations for Boating Navigation**

<b>Reservoir Elevation (feet msl)</b>	<b>Boating Issues</b>
3680	Buoys are placed for safe navigation
3626	Navigation for tour boats – several areas closed
3620	Navigation for recreational boats – several areas closed

### 3.9.3.2.1.1 Lake Powell Safe Boating Capacity

Recreational boating is the most frequent type of boating activity on Lake Powell, with an estimated 1.5 million boaters per year. One of the most popular activities at Lake Powell is to take houseboats and motor boats for multiple day excursions to explore the reservoir.

The number of boats that Lake Powell can safely accommodate at one time (i.e., safe boating capacity) is based on a 1977 Bureau of Reclamation standard of nine surface acres per boat (Reclamation, March 1995). Therefore, the amount of water storage in Lake Powell directly influences the surface area of the reservoir and the number of boats that can safely be on the reservoir. Table 3.9-8 lists Lake Powell surface areas for baseline conditions and alternatives in the year 2015 and identifies the safe boating capacity of the reservoir at those elevations based on an assumed maximum safe density of 9 acres per boat. The surface area of Lake Powell is reduced approximately 9 to 10 percent for each incremental 20-foot drop.

**Table 3.9-8  
Lake Powell Safe Boating Capacity at Water Surface Elevations**

<b>Scenario</b>	<b>Elevation in Year 15 (feet msl)</b>	<b>Water Surface Area (acres)</b>	<b>Safe Boating Capacity<sup>1</sup></b>
Baseline Conditions	3663	133,200	14,800
Flood Control Alternative	3664	133,800	14,867
Six State Alternatives	3650	124,700	13,856
California Alternative	3642	119,600	13,289
Shortage Protection Alternative	3638	116,900	12,989

<sup>1</sup> Number of boats assuming safe density of 9 acres per boat

While safe reservoir boating carrying capacity is reduced at lower lake elevations, there may be additional shoreline camping available due to more exposed beaches. However, boating capacity is more constrained by safe boating densities than by the availability of camping sites (Combrink and Collins 1992).

### 3.9.3.2.2 Lake Mead Boating Navigation and Safety

Similar to the navigation system on Lake Powell, regulatory buoys and other marking devices are used on Lake Mead to warn boat operators of dangers, obstructions, changes in subsurface conditions in the main channel or side channels.

As with Lake Powell, the main channel of the old Colorado River bed forms the primary travel corridor on Lake Mead and is marked its entire length with buoys for

boating guidance. In addition, regulatory buoys are placed in areas where there may be a danger for safe passage.

Excursions into the Grand Canyon are a popular activity at Lake Mead. Boats usually launch at either Pearce Ferry, South Cove or Temple Bar (as shown previously on Map 3.9-2). There are no developed facilities upstream of Temple Bar. Points of interest in the Grand Canyon include Columbine Falls, Bat Cave, Spencer Creek, and Separation Canyon. In addition to sightseeing being a popular activity, many boaters include overnight camping stays on these excursions (Reclamation, March 1995).

The upper arms and inflow areas of the reservoir are considered dangerous for navigation due to shifting subsurface sediments. In the main channel of the reservoir, the Grand Wash Cliffs area is the beginning of the dangerous navigation conditions, and no houseboats are allowed beyond this point (NPS, undated).

Over the years, sediment has built up in the section of the reservoir between Grand Wash and Pearce Ferry. When lake elevations fall below 1170 feet msl, the sediment is exposed as mud flats and there is no well-defined river channel. As a result, the area is too shallow for motor boats to navigate upstream and into the lower reaches of the Grand Canyon. With fluctuating flows, even smaller crafts have a difficult time accessing the area because of the shifting nature of the channel (Reclamation, March 1995). For the purposes of this analysis, 1170 feet msl is considered as an important elevation for navigation.

In addition to the boating navigation issues summarized in the table above, there are swimmer safety issues at Lake Mead. At Gypsum Wash (between Las Vegas Bay and Government Wash) there are cliffs that are popular with recreationists for jumping into the lake. However, when lake elevations are below 1180 feet msl, the water is too shallow for cliff jumping from this location. Another jumping spot that was popular during the late 80s when reservoir levels were down is an area called "33 Hole." This location is popular for cliff jumping when the lake elevation reaches 1165 feet msl. Cliff jumping at both locations is discouraged by the NPS for safety reasons (Burke, 2000). Since the activity is discouraged, the identified elevations were not considered as thresholds for evaluation of effects.

### **3.9.3.2.3 Lake Mead Safe Boating Capacity**

The LMNRA receives approximately ten million visitors annually. Of those that participate in water-based recreation, most either swim, boat, fish, sailboard, use paddlecraft, or scuba dive (Reclamation, August 1996). As with Lake Powell, a safe boating density of 9 surface acres per boat was assumed for the reservoir, and safe boating capacities have been determined based on reservoir elevation/surface area relationships. However, there is no daily or peak boating use information available to establish the relationship between actual boating densities and the safe boating capacity values shown below.

At full pool, the operating surface area is 153,235 acres. Using the same 1977 Bureau of Outdoor Recreation standard of nine surface acres per boat, Lake Mead's safe boating capacity at full storage is approximately 17,000. As pool elevation recedes, the surface area available for boats based on the safe boating density calculations also diminishes. Table 3.9-9 shows Lake Mead surface area under the predicted pool elevations for baseline conditions and the alternatives in the year 2015 and identifies the safe boating capacity of the reservoir based on an assumed maximum safe density of 9 acres per boat.

**Table 3.9-9**  
**Lake Mead Safe Boating Capacity at Water Surface Elevations**

<b>Scenario</b>	<b>Elevation in Year 15 (feet msl)</b>	<b>Water Surface Area (acres)</b>	<b>Safe Boating Capacity<sup>1</sup></b>
Baseline Conditions	1170	125,900	13,989
Flood Control Alternative	1171	126,300	14,033
Six State Alternatives	1156	116,000	12,889
California Alternative	1147	121,000	13,944
Shortage Protection Alternative	1144	108,200	12,022

<sup>1</sup> Number of boats assuming safe density of 9 acres per boat

### 3.9.3.3 ENVIRONMENTAL CONSEQUENCES

Boating navigation and safe boating densities on Lake Powell and Lake Mead are dependent upon water surface elevations. As lake levels fluctuate, hazards, such as exposed rocks at lower pool elevations or different navigational patterns at higher elevations, may become evident. At low pool elevations, special buoys or markers must be placed to warn boaters of navigational hazards. In addition, signs may be placed in areas that are deemed unsuitable for navigation.

Assessment of environmental consequences of the alternatives on boating navigation and safety is based on model output, described in detail in Section 3.3. The probability of effects under baseline conditions and the alternatives were determined through identifying the probability of avoiding a representative "threshold" pool elevation during the 50-year period. The selection of the threshold pool elevation is based on the known boating navigation issues discussed in the Affected Environment section above. The probabilities of the reservoirs remaining above the identified threshold elevations are identified for baseline conditions and the interim surplus criteria alternatives, and comparisons made between the incremental differences in probabilities of avoidance.

In addition to navigation issues that occur at low pool elevations, the number of boats that can safely be accommodated on the reservoir at one time (safe boating capacity) is

also a reservoir boating issue. As discussed previously, the lack of boating use data and spatial modeling of the effects of the alternatives on shoreline conditions precludes a quantitative or qualitative assessment of the impacts associated with the alternatives. In general, as pool elevation recedes, so does the reservoir surface area and the number of boats that can safely be accommodated on the reservoir. Therefore, the alternatives that result in the greatest potential for lower surface elevations would tend to increase the likelihood of exceeding safe boating densities. However, without current and projected boating use levels for comparison to surface areas under the alternatives, it cannot be determined whether the change in available surface area would result in an exceedance of the calculated safe boating capacities shown in Tables 3.9-8 and 3.9-9.

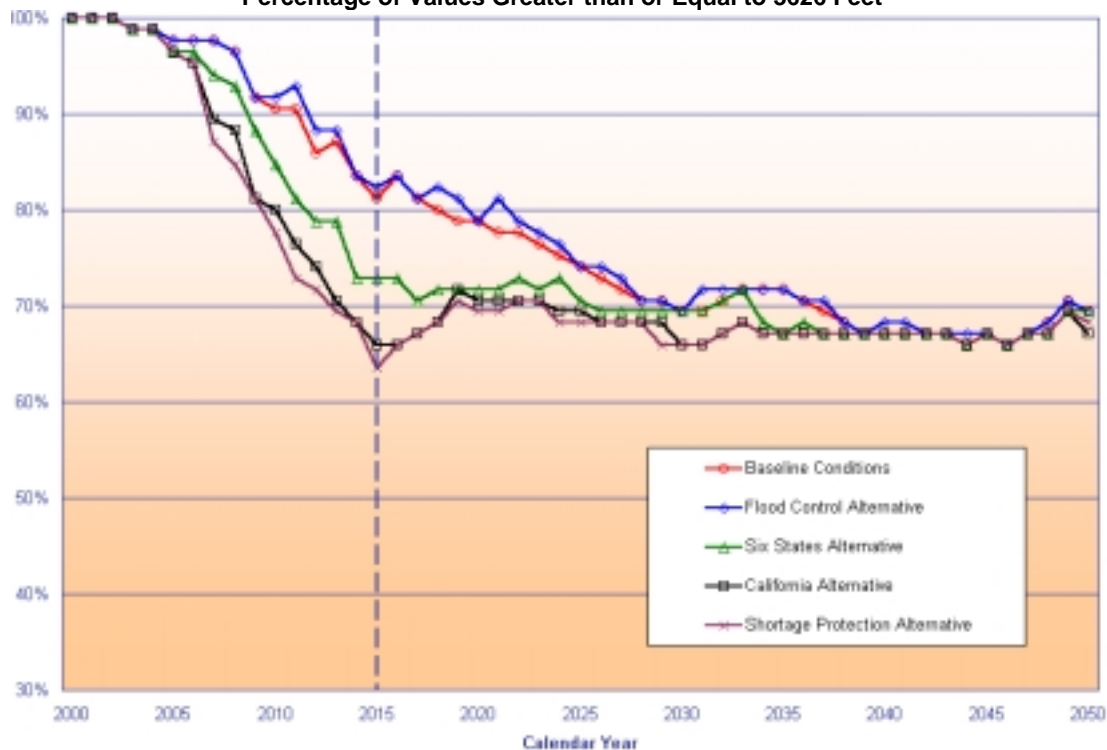
#### **3.9.3.3.1 Lake Powell**

For Lake Powell, a reservoir pool elevation of 3626 feet msl has been identified as a representative threshold for boating navigation. At this elevation, two areas on Lake Powell are closed to boating. One area is around Castle Rock and the other is near Padre/Gregory Butte. At a surface elevation of 3626 feet msl, boats leaving Wahweap, headed up reservoir (east), must detour 8.5 miles around the southern end of Antelope Island. Farther east, boats must detour 4.5 miles around the Padre/Gregory Butte area.

Figure 3.9-1 (presented previously) shows projected yearly elevations for baseline conditions and the alternatives over the projected 50-year period, based on median elevations.

Figure 3.9-6 depicts the probability of avoiding pool elevations below 3626 feet msl for the under baseline projections and each of the alternatives. Table 3.9-10 presents a tabular comparison of the probabilities associated with years 1 through 15 and years 16 through 50. Modeling results indicate that the probability of avoiding elevation 3626 feet msl would decrease moderately (from 100 to 70 percent) in the next 50 years under any of the alternatives. Baseline condition projections are the least likely to result in pool elevations below 3626 feet msl, whereas the Shortage Protection Alternative is most likely. The California and Six States alternatives have probabilities in between baseline conditions and the Shortage Protection Alternative.

**Figure 3.9-6**  
**Lake Powell End-of-Year Water Elevations**  
**Comparison of Surplus Alternatives to Baseline Conditions**  
**Percentage of Values Greater than or Equal to 3626 Feet**



**Table 3.9-10**  
**Comparison of Probabilities of Avoidance of Lake Powell**  
**Surface Elevation of 3626 Feet**

Projected Condition	Probability of Avoidance of Elevation 3626 Feet	
	Years 1 through 15	Years 16 through 50
Baseline Conditions	81%	81%-68%
Flood Control Alternative	82%	82%-68%
Six States Alternative	73%	73%-68%
California Alternative	66%	66%-68%
Shortage Protection Alternative	64%	64%-68%

### 3.9.3.3.1.1 Baseline Conditions

Lake Powell pool elevations would tend to decline the least under the baseline condition as compared to three of the four other alternatives. At year 2015, there is a probability of 81 percent that pool elevations would not be below 3626 feet msl as shown on Table 3.9-10. From years 2016 to 2050, the probability of avoidance would gradually decrease by about 13 percent (81 to 68 percent).

#### **3.9.3.3.1.2 Flood Control Alternative**

The probability that lake levels would remain above 3626 feet msl under the Flood Control Alternative is approximately the same as compared to baseline conditions. The probability of avoiding pool elevations below 3626 feet msl would increase by about 1 percent under the Flood Control Alternative as compared to baseline conditions. In the year 2015, there is an 82 percent probability that pool elevations would be above elevation 3626 feet msl, as shown in Table 3.9-10. From year 2016 to 2050 the probability of avoidance decreases to about 68 percent.

#### **3.9.3.3.1.3 Six States Alternative**

The probability that lake levels would remain above 3626 feet msl under the Six States Alternative is lower than under baseline conditions. The probability of avoidance would decrease by about 7 percent under the Six States Alternative as compared to baseline conditions. In general, probabilities indicate that declining pool elevations could occur five to ten years prior to the same pool elevations under baseline conditions. In the year 2015, there is a 73 percent probability that pool elevations would be above elevation 3626 feet msl. From year 2016 to 2050 the probability of avoidance decreases to about 68 percent.

#### **3.9.3.3.1.4 California Alternative**

Under the California Alternative, projections indicate probabilities of avoiding pool elevations lower than 3626 feet msl lower than baseline conditions by about 15 percent. In general, declining pool elevations would occur about eight to ten years prior the same pool elevations under baseline conditions. In the year 2015, there is a 66 percent probability that pool elevations below 3626 feet msl would be avoided as shown in Table 3.9-10. From year 2016 to 2050 the probability of avoidance would increase slightly to 68 percent.

#### **3.9.3.3.1.5 Shortage Protection Alternative**

Lake Powell pool elevations under the Shortage Protection Alternative would have the lowest probability of remaining above 3626 feet msl. On average, the probability of avoidance is 17 percent lower under the Shortage Protection Alternative than under baseline conditions as shown on Figure 3.9-6. In general, declining pool elevations would occur approximately 10 years before similar pool elevations under baseline conditions. In the year 2015, there is a 64 percent chance that pool elevations below 3626 feet msl would be avoided. Between year 2016 and 2050, the probability of avoidance would increase slightly to 68 percent.

### 3.9.3.3.2 Lake Mead

For Lake Mead, a reservoir pool elevation of 1170 feet msl was identified as a representative threshold for boating navigation. As described in the Affected Environment section above, at elevation 1170 feet msl, the upstream section of the reservoir between Grand Wash Cliffs and Pearce Ferry is an exposed mudflat, there is no well-defined river channel, and motor boats have a difficult time navigating upstream into the lower reaches of the Grand Canyon. With fluctuating flows, even smaller craft have difficulty navigating because of the shifting nature of the channel (Reclamation, March 1995). Figure 3.9-4 (presented previously) shows projected yearly elevations for baseline conditions and the alternatives over the projected 50-year period, based on median elevations.

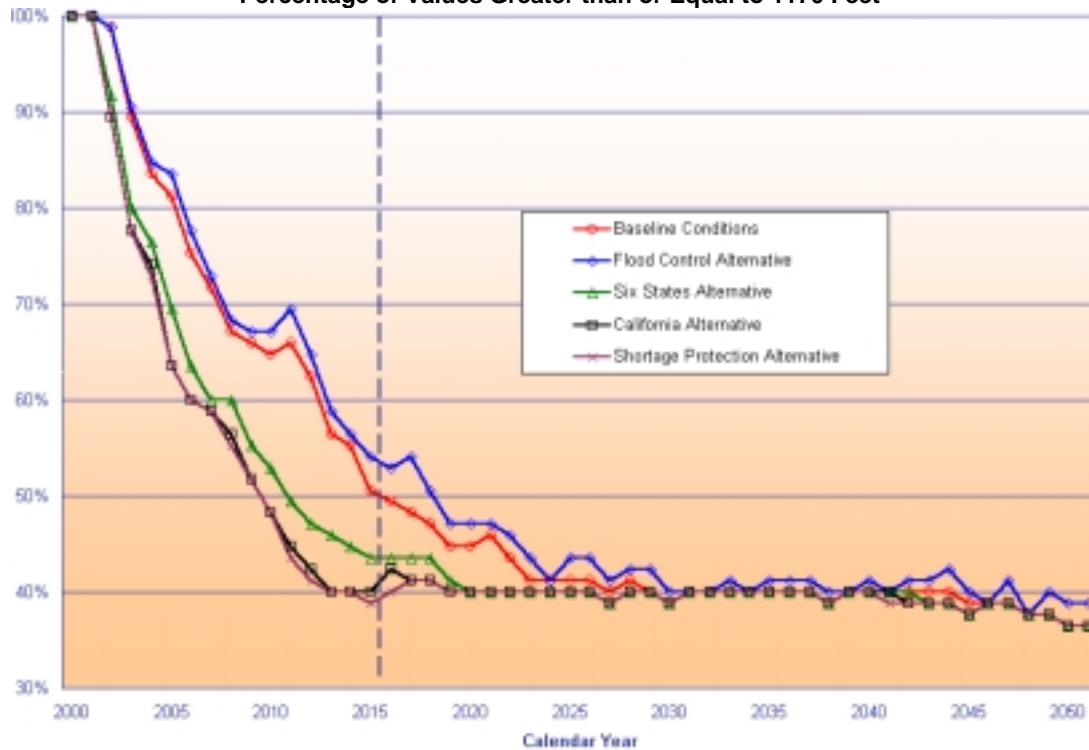
Figure 3.9-7 below, depicts the probability of avoiding pool elevations below 1170 feet msl for the baseline condition and each of the alternatives. Table 3.9-11 presents a tabular comparison of the probabilities associated with years 1 through 15 and years 16 through 50.

**Table 3.9-11**  
**Comparison of Probabilities of Avoidance of Lake Mead**  
**Surface Elevation of 1170 Feet**

Projected Condition	Probability of Avoidance of Elevation 1170 Feet	
	Years 1 through 15	Years 16 - 50
Baseline Conditions	50%	50%-40%
Flood Control Alternative	55%	55%-40%
Six States Alternative	43%	43%-40%
California Alternative	40%	40%
Shortage Protection Alternative	39%	39%-40%

Under baseline conditions and each of the alternatives, there is an increased potential for the occurrence of pool elevations in Lake Mead declining over the initial 30-year period of analysis. Baseline condition projections indicate the highest potential for elevations to remain above 1170 feet msl, whereas the Shortage Protection Alternative has the lowest potential. The California and Six States alternatives have probabilities between baseline and the Shortage Protection Alternative.

**Figure 3.9-7**  
**Lake Mead End-of-Year Data Water Elevations**  
**Comparison of Surplus Alternatives to Baseline Conditions**  
**Percentage of Values Greater than or Equal to 1170 Feet**



### 3.9.3.3.2.1 Baseline Conditions

Probabilities of avoidance of Lake Mead pool elevations below 1170 feet msl under baseline conditions would decline to as low as 40 percent over the 50-year period of analysis. By year 2015, modeling results indicate a 50 percent probability of Lake Mead elevations above 1170 feet msl, as shown in Table 3.9-11. From years 2016 to 2030, the probability of avoidance would decline by 10 percent to about 40 percent, and remain at approximately 40 percent through the remaining 50-year period of analysis. The decline in Lake Mead elevation can be attributed to increases in upper basin uses and hydrology.

### 3.9.3.3.2.2 Flood Control Alternative

Pool elevations under the Flood Control Alternative would have a decreased probability to decline below a surface elevation of 1170 feet msl as compared to baseline conditions. On average, the Flood Control Alternative is 4 percent less likely to occur below elevation 1170 feet msl than baseline conditions as shown on Figure 3.9-6. By year 2015, modeling results indicate a 55 percent probability of Lake Mead elevations above 1170 feet msl, as shown in Table 3.9-11. From year 2016 to

2030, the probability of avoidance would decline by 15 percent to 40 percent, and would remain around 40 percent until 2050.

#### **3.9.3.3.2.3 Six States Alternative**

Pool elevations under the Six States Alternative would have lower probability of avoiding surface elevations below 1170 feet msl as compared to baseline conditions. On average, the Six States Alternative is 10 percent more likely to result in elevations below 1170 feet msl as compared to baseline conditions as shown on Figure 3.9-7. By year 2015, the modeling results indicate a 43 percent probability that pool elevations would decline to 1170 feet msl or lower. From year 2016 to 2030, the probability of avoidance would decline by 3 percent to 40 percent, and would remain around 40 percent until 2050. In general, the decline in pool elevations would occur 2 to 6 years sooner under the Six States Alternative as compared to baseline conditions.

#### **3.9.3.3.2.4 California Alternative**

Pool elevations under the California Alternative have a lower probability of avoiding surface elevations below 1170 feet msl as compared to baseline conditions. On average, the California Alternative has a 13 percent greater likelihood to decline to below elevation 1170 feet msl as compared to baseline conditions. By year 2015, there is a 40 percent probability that pool elevation would decline to 1170 feet msl or lower as shown on Table 3.9-11. From year 2016 to 2030, the probability of avoidance would remain around 40 percent until 2050. In general, the decline in pool elevations would occur 4 to 8 years sooner under the California Alternative as compared to baseline conditions.

#### **3.9.3.3.2.5 Shortage Protection Alternative**

Pool elevations under the Shortage Protection Alternative would have the greatest probability of declining below 1170 feet msl. On average, the Shortage Protection Alternative is 15 percent more likely to decline to below 1170 feet msl than under baseline conditions. By year 2015, there is a 39 percent probability that pool elevation would decline to 1170 feet msl or lower as shown on Table 3.9-11. After year 2016, the probability of avoidance would remain at approximately 40 percent until 2050. In general, the decline in pool elevations would occur 4 to 8 years sooner as compared to baseline conditions.

### **3.9.4 RIVER AND WHITEWATER BOATING**

As discussed in Section 3.2, the Adaptive Management Program provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources and using the results to develop recommendations for modifying operating criteria and other resource management actions. It has been determined that the interim surplus criteria alternatives are not expected to affect flows in the Colorado

River between Glen Canyon Dam and Lake Mead. While the yearly allocations of water from Lake Powell will slightly vary under each of the alternatives as compared to baseline conditions, flow release patterns in the Colorado River below Glen Canyon Dam would continue to be monitored by the Adaptive Management Program (see Section 3.2.3).

The only effect that the implementation of the interim surplus criteria alternatives would have on whitewater boaters would be the lowered pool elevations in Lake Mead. Whitewater boaters on the Colorado River often end their trips in Lake Mead. Pearce Ferry is the preferred Lake Mead take out for boaters, however, this may not be available when there are low pool elevations in the reservoir. At pool elevations of 1170 feet msl, the Pearce Ferry take out is inaccessible and boaters must paddle an additional 16 miles to South Cove for take out (Henderson, 2000). This includes paddling through the section of reservoir between Pearce Ferry and Grand Wash. The interim surplus criteria alternatives under consideration would each increase the potential for reduced Lake Mead surface elevations over the 50-year period of analysis as compared to baseline conditions. A take out is also available at Diamond Creek, upstream of Lake Mead at the Hualapai Reservation. The Hualapai maintain the take out area and road and charge a fee for take out. The Hualapai Tribe also conducts river trips from Diamond Creek (on the Colorado River) to Pearce Ferry. This concession may be affected if trips encounter changes in availability of the Pearce Ferry take out.

### **3.9.5 RESERVOIR FISHING**

This section considers potential effects of the interim surplus criteria alternatives on recreational opportunities associated with reservoir fishing at Lake Powell and Lake Mead.

#### **3.9.5.1 METHODOLOGY**

The discussion of the affected environment for reservoir fishing is based on a review of published documents. Much of this information was derived from the following sources: for Lake Powell, the *Fish Management Plan, Glen Canyon National Recreation Area* (NPS, 1996); and for Lake Mead, the *Desert Lake View Newspaper, Fall/Winter 1999*.

Assessment of potential impacts on reservoir fishing from the alternatives are based on information presented in other sections of the document regarding sport fishery populations (Section 3.7), reservoir shoreline facilities (Section 3.9.2) and reservoir navigation (Section 3.9.3). There were no specific reservoir pool elevation thresholds identified from the literature reviewed. Catch rates for reservoir fishing are assumed to be directly related to reservoir habitat discussed in Section 3.7, Aquatic Resources. Fishing satisfaction is assumed to be directly related to the general recreation issues of boating access to the water via shoreline facilities, and boating navigation potential for

hazards or reservoir detours due to low pool elevations. As discussed in Section 3.7, catch rates are not expected to be affected by fluctuations in pool elevations.

### **3.9.5.2 AFFECTED ENVIRONMENT**

#### **3.9.5.2.1 Fishing in Lake Powell**

Lake Powell is a popular fishing destination. Over 3 million people visit the GCNRA annually, and those that fish spend a total of close to 2 million angler hours in pursuit of a variety of sport fish. Currently, the catch rate is 0.3 fish per hour, a number that has declined in recent years due to angling pressure. Approximately one-half of the fish caught are harvested, which results in an average annual harvest of 300,000 fish (NPS, 1996).

As discussed in Sections 3.7 and 3.8, native Colorado River species have not done well in the reservoir environment. While some natives may spawn in the reservoir, it is believed that the majority of young are eliminated by sport fish predators. The predominant sport fishery in Lake Powell revolves around striped bass. The striped bass depend on threadfin shad as a food source, so it is critical to maintain a balanced shad population for the stripers. The threadfin shad in Lake Powell are at the northernmost portion of their range and are very sensitive to fluctuations in water temperature. In addition to striped bass, Lake Powell supports largemouth and small mouth bass, walleye, channel catfish, bluegill, and black crappie. Lake Powell has been stocked with fish almost annually beginning in 1963 (NPS, 1996).

Recent studies have indicated a trend of increasing biocontaminant concentration in aquatic organisms near the dam. Selenium has been found in the plankton and in striped bass. Although there has not yet been any apparent negative impacts on striped bass reproduction, selenium can pose a health risk to anglers from consumption. If the presence of selenium continues, educating the anglers and performing risk assessment studies may be necessary (NPS, 1996).

#### **3.9.5.2.2 Fishing in Lake Mead**

Fishing is a favorite activity at Lake Mead. Largemouth bass, striped bass, channel catfish, rainbow trout, bullhead catfish, sunfish, crappie, and bluegill can be found in Lake Mead. To fish from shore, a valid license is required from the state where the fishing occurs. If fishing from a boat or other flotation device, a use stamp from the other state is required. Rainbow trout fishing also requires an additional stamp. Children under 14 are not required to have a license.

Lake Mead is famous for its striped bass, with an occasional catch weighing over 40 pounds, although weights of 3 to 5 pounds are more common. Fishing for striped bass or largemouth bass is good throughout the entire lake, but panfish and catfish are more prevalent in the upper Overton Arm.

The NDOW stocks rainbow trout from late December through the spring months. The razorback sucker, a protected fish species, must be returned to the water immediately and carefully, if caught.

Fishing is generally better in the fall months of September, October and November although Lake Mead is open 24 hours a day, year-round. Larger fish are caught by deep water trolling in spring from March through May.

### **3.9.5.3 ENVIRONMENTAL CONSEQUENCES**

#### **3.9.5.3.1 Reservoir Fishing**

Reduced reservoir surface elevations could affect recreational reservoir fishing by decreasing the number of fishing days and angler satisfaction. The lower pool elevations could cause temporary or permanent closure or relocation of shoreline facilities, thus requiring the boat angler to either travel to another launch site or possibly forego fishing that day. Also, navigational issues, such as the closure of areas of the reservoirs, could increase travel times to desired fishing locations and result in reduced angler satisfaction. Lower pool elevations may make some shoreline fishing areas inaccessible. In addition, as discussed in Section 3.9.3.2, as pool elevations lower, the surface area available for boats based on the safe boat density calculations also diminishes.

No direct information on angler success rates or angler satisfaction is available, as such potential effects were determined indirectly through consideration of potential effects on sport fishery production and water access for boat and shore anglers. The effects of the alternatives on sports fishery production are discussed in detail in Section 3.7.4. The effects on boating access, including shoreline facilities that provide access to the water for boat angling, and navigational constraints on boating are discussed above in Sections 3.9.2 and 3.9.3.

As discussed in Section 3.7.4, Sport Fisheries, potential reductions in surface elevations associated with both baseline projections and the alternatives is not expected to affect sport fishery composition or quantities within the reservoirs. As such, angler success rates at Lake Powell and Lake Mead would not be reduced.

The potential for reduced reservoir surface elevations under baseline conditions and the alternatives is discussed in Section 3.9.2.3, and not repeated here. In summary, baseline projections indicate the lowest probability of reservoir level declines and potential reductions in angler satisfaction over the 50-year period of analysis. The Shortage Protection Alternative would result in the highest probability for declines in surface elevations and potential reductions in angler satisfaction. The California and Six States Alternatives would have generally similar probabilities of surface elevation declines and potential reductions in angler satisfaction with probabilities between those of baseline conditions and the Shortage Protection Alternative.

### **3.9.6 RECREATIONAL FACILITIES OPERATIONAL COSTS**

In order to keep reservoir marinas, boat launching and public use beaches and shoreline access operational, the facility owner/operators and the agencies providing utility connections must respond to fluctuating pool elevations. This section focuses on the operational and capital costs to keep recreational facilities in operation as the reservoir surface elevations change.

Potential revenue effects from changes in recreation use are not considered. As discussed above, it is not expected that baseline conditions or interim surplus criteria would result in facilities' closure, as most facilities can be relocated to maintain operation under lower reservoir elevation conditions.

#### **3.9.6.1 METHODOLOGY**

Information in the affected environment section was compiled after review of available published and unpublished sources and through personal communication with NPS specialists. Available data do not cover all facilities. Furthermore, the analysis is generally based on professional judgement extrapolating from limited historical data. However, the analysis provides a useful approximation of the order of magnitude of costs to recreational facilities that may be incurred under projections and each of the alternatives.

Using data associated with facilities' relocation costs, projections of the costs associated with declines have been made using results of the hydrologic analysis discussed in detail in Section 3.3. Calculations of potential costs use model projections associated with the 50 percent exceedence probability elevations. The analysis quantifies costs associated with the 50 percent probability elevations for years 2001 through 2015. This simplified methodology addresses multi-year changes in elevation, and does not consider costs associated with facilities adjustments to accommodate monthly fluctuations.

#### **3.9.6.2 AFFECTED ENVIRONMENT**

The following sections discuss costs associated with relocation of reservoir marinas and boat launching facilities at Lake Powell and Lake Mead. Many of the facilities at Lake Powell and Lake Mead were constructed when the reservoirs were near their maximum pool elevations of 3700 feet msl and 1210 feet msl, respectively.

##### **3.9.6.2.1 Lake Powell**

The costs of fluctuating pool elevations on Lake Powell marinas and boat-launching facilities were calculated by Combrink and Collins (1992). The study calculated operating costs for one-foot fluctuations (termed "normal adjustments") and for adjustments when the pool fluctuation exceeds 25 feet (termed "special adjustments").

The normal adjustments are adjustments made within the range of regular operations and are done routinely as water levels change during the year. Special adjustments include relocations of anchors and extensions of cables and utilities. The study found that major capital investments would be needed and cost estimates were developed based on a 50-foot decline in pool elevations. Table 3.9-12 presents the costs incurred per adjustment as the data was collected. In order to ease use of the data to compare different alternatives, the data has been converted into a cost per foot of fluctuation. Data was collected in 1989; thus it is updated to year 2000 price levels.

**Table 3.9-12**  
**Costs Associated with Adjustments to Lake Powell Recreation Facilities**

Adjustment Cost Category <sup>1</sup>	Cost per Adjustment		Cost per Foot
	1989 Price Level <sup>2</sup>	2000 Price Level <sup>3</sup>	
Operating Cost for a Normal Adjustment (based on one-foot fluctuation)	\$1,275	\$1,721	\$1,721
Operating Cost for a Special Adjustment (fluctuations exceeding 25 feet)	\$33,460	\$45,171	\$1,807
Capital Cost for each 50-foot drop	\$2,000,000	\$2,700,000	\$54,000
<b>Total Cost per Foot</b>			<b>\$57,528</b>

1. Operating costs are the cost of adjusting the existing facilities for fluctuations and consist of labor hours. Capital costs consist of construction of ramp extensions, utility line extensions and relocations.
2. Combrink and Collins.
3. Consumer Price Index-All Urban Consumers. 1989 average is 124.0. March 2000 is 167.8. Adjustment factor:  $167.8/124.0 = 1.35$

Table 3.9-12 indicates there are costs associated with even minor changes in pool elevations. However, the cost of capital improvements required to extend utilities and access below the range of elevations that can be accommodated by existing infrastructure is much larger than the operating costs incurred within the capacity of the existing infrastructure.

It should be noted that many of the Lake Powell shoreline facilities were extended in 1992/93 to accommodate reduced Lake Powell surface elevation down to 3612 feet msl. Due to these extensions, the actual costs of relocating facilities in the event of future Lake Powell surface elevation declines may be lower than those indicated in the analysis.

### **3.9.6.2.2 Lake Mead**

NPS provided information on costs associated with relocation of facilities at Lake Mead. The operating levels range between full pool elevation (1210 feet msl) to 1180 feet msl. When Lake Mead declines to 1180 feet msl, adjustments need to be made to the major facilities. Costs for each of the major facilities at year 2000 price

levels to make these adjustments range from \$560,000 to \$970,000. NPS has also determined that any additional incremental drops of 20 feet in elevation will incur additional costs, ranging from \$480,000 to \$800,000 (Henderson, 2000).

Costs associated with fluctuating pool elevations are available for federally-owned facilities at LMNRA from unpublished data assembled by the Resource Management Office, Lake Mead NRA (Henderson, Burke and Vanderford, April 17 and 18, 2000). In addition, Overton Beach Marina (letter dated March 29, 2000) and Lake Mead Resort (letter dated April 11, 2000) provided information to Reclamation indicating the costs associated with fluctuating reservoir elevations. Table 3.9-13 presents these costs.

**Table 3.9-13**  
**Costs Incurred to Recreational Facilities from Lake Mead Pool Fluctuations**  
**(Year 2000 Price Level)**

Line No.	Fluctuation	Cost per Increment
1	Cost to LMNRA facilities of surface elevation occurrence below 1180 feet. <sup>1</sup>	\$ 6,011,000
2	Cost to LMNRA facilities at elevation 1160 and at each additional 20-foot drop. <sup>1</sup>	\$ 5,080,000
3	Cost to Lake Mead Resort Marina from a 20-foot drop in elevation <sup>2</sup>	\$ 91,400
4	Cost to Overton Beach Marina facilities from a fluctuation from elevation 1212 to elevation 1150 (62 feet) <sup>3</sup>	\$ 60,000
5	Cost to Overton Beach Marina Facilities from a fluctuation from elevation 1150 to 1130 feet msl (20 feet) <sup>3</sup>	\$ 425,000
6	Cost to Temple Bar Resort from a 10-foot drop <sup>4</sup>	\$ 12,500
7	Cost to Echo Bay Resort from a 20-foot drop from elevation 1213 feet msl to 1193 feet msl. <sup>5</sup>	\$ 38,400

<sup>1</sup> Unpublished data from Lake Mead NRA.

<sup>2</sup> Letter dated April 11, 2000, from Lake Mead Resort to Reclamation. The letter quantifies cost for a drop from current pool elevations. It also notes that larger drops could result in abandonment of the basin within which the resort is located.

<sup>3</sup> Letter dated March 29, 2000, from Overton Beach Marina to Reclamation.

<sup>4</sup> Letter dated March 27, 2000, from Temple Bar Resort. Midpoint of range (\$10,000 to \$15,000) is used. Letter further notes that a drop below 1125 feet msl would require a complete relocation of the marina including buildings located on land.

<sup>5</sup> Letter dated March 16, 2000, from Echo Bay Resort to Reclamation.

### 3.9.6.3 ENVIRONMENTAL CONSEQUENCES

#### 3.9.6.3.1 Lake Powell

As discussed in the methodology section, an estimate can be made of the cost impacts of the alternatives on Lake Powell recreational facilities under some simplifying conditions. Estimates in this section are for the aggregate relocation costs associated with all identified Lake Powell shoreline facilities.

Table 3.9-14 shows the incremental costs that would be incurred from Lake Powell surface elevation decreases associated with the median elevation projections for baseline conditions and each alternative from 2001 through 2015 of the analysis (Figure 3.9-1 presents these elevations graphically). These impacts are based on a cost of \$57,528 per foot change in elevation developed based on the information shown in Table 3.9-12, above.

**Table 3.9-14**  
**Costs Associated with Potential Relocation of Lake Powell Recreational Facilities**  
**Under Alternatives Compared to Baseline Conditions<sup>1</sup>**  
**(Year 2000 Price Level)**

<b>Alternative</b>	<b>Elevation in Year 15<sup>2</sup> (feet msl)</b>	<b>Elevation Below Baseline Conditions (feet)</b>	<b>Incremental Cost over 15-Year Period<sup>3</sup></b>
Baseline Conditions	3663	0	-----
Flood Control Alternative	3664	-1	(\$57,528) <sup>4</sup>
Six States Alternative	3650	13	\$ 747,864
California Alternative	3642	21	\$ 1,208,088
Shortage Protection Alternative	3638	25	\$1,438,200

<sup>1</sup> Assumes pool elevation decreases constantly over time, following 50% chance of exceedence elevation.

<sup>2</sup> Based on 50 percent probability of exceedence elevation projected from modeling.

<sup>3</sup> Table 3.9-12. \$57,528 per foot.

<sup>4</sup> The median elevations of the Flood Control Alternative are slightly higher than under baseline projections. As such, the incremental difference indicates a net savings under the Flood Control Alternative.

By 2050, the probability of exceedence elevation of all alternatives is the same (3662.24 feet msl) and no difference in costs would occur.

#### 3.9.6.3.2 Lake Mead

As discussed in the methodology section, an estimate can be made of the cost impact of the alternatives on Lake Mead recreational facilities using certain assumptions.

Table 3.9-15 shows estimated increase in costs that would be incurred from Lake Mead surface elevation decreases associated with the median elevation projections for

each alternative as compared to baseline conditions from 2001 through 2015 of the analysis (Figure 3.9-4 presents the median elevations graphically).

**Table 3.9-15**  
**Costs Associated with Potential Relocation of Lake Mead Recreational Facilities**  
**Under Alternatives Compared to Baseline Conditions<sup>1</sup>**

<b>Alternative</b>	<b>Elevation in Year 15 (feet msl)<sup>2</sup></b>	<b>Elevation Below Baseline Conditions</b>	<b>Incremental Cost over 15-Year Period</b>
Baseline Conditions	1171	N/A	NA
Flood Control Alternative	1171	0	0
Six States Alternative	1156	15	\$ 5,222,300 <sup>3</sup>
California Alternative	1147	24	\$5,234,800 <sup>4</sup>
Shortage Protection Alternative	1144	27	\$ 5,234,800 <sup>4</sup>

<sup>1</sup> Assumes pool elevation decreases constantly over time, following 50% chance of exceedence elevation.

<sup>2</sup> Based on 50 percent probability of exceedence elevation projected from hydrologic modeling.

<sup>3</sup> Lines 2, 3, 6 and 7 from Table 3.9-13.

<sup>4</sup> Lines 2, 3, 7 and twice Line 6 from Table 3.9-13

By 2050, the 50 percent probability of exceedence elevation of all alternatives is essentially the same (1123.14 feet msl to 1123.09 feet msl), and no differences in cost would occur.